THE No 1 UK MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

EPE EVERYDAY PRACTICAL ELECTRONICS

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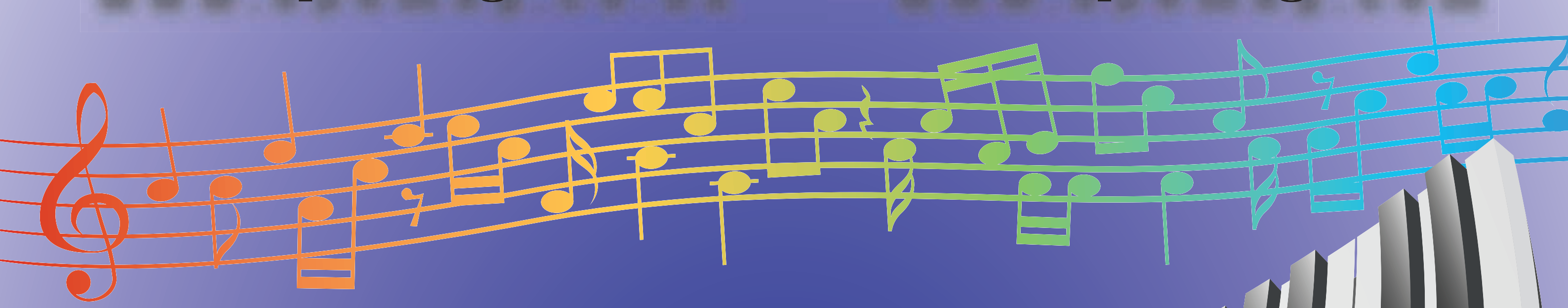

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- 18 'instruments'

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PROJECTS . . . THEORY . . .
NEWS . . . COMMENT . . .
POPULAR FEATURES . . .

VOL. 37. No. 7 JULY 2008

EPE EVERYDAY PRACTICAL ELECTRONICS

INCORPORATING ELECTRONICS TODAY INTERNATIONAL

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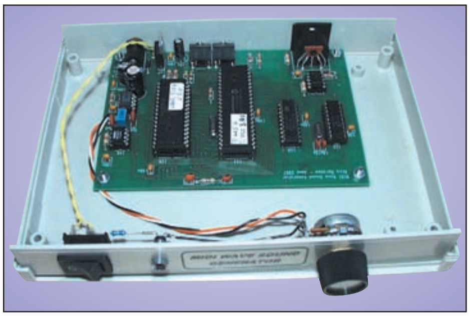


Our August 2008 issue will be published on Thursday, 10 July 2008, see page 80 for details.

Projects and Circuits

Series and Features

Regulars and Services

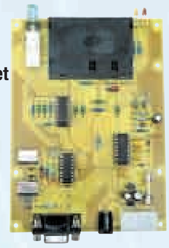
POPULAR KITS

These are some of our most popular kits and there is something for eveyone. They are designed for ease of construction and robust reliability. All of our kits are supplied with quality fibreglass PCBs, board components and clear English instruction. Jaycar kits can be built with confidence.

Full Function Smart Card Reader / Programmer Kit

KC-5361 £15.95 + postage & packing

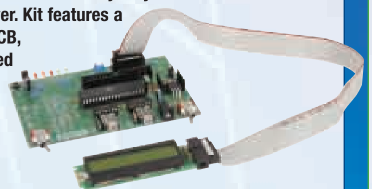
Program both the microcontroller and EEPROM in ISO-7816 compliant Gold, Silver and Emerald wafer cards. Powered by 9-12 VDC wall adaptor or a 9V battery. Kit supplied with PCB, wafer card socket and all electronic components. PCB measures: 141 x 101mm



Audio Playback Adaptor for CD-ROM Drives

KC-5459 £19.00 + post & packing

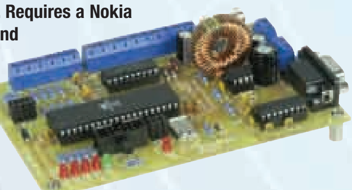
Put those old CD-ROM drives to good use as CD players using this nifty adaptor kit. The adaptor accepts signals from common TV remote controls and operates the audio functions of the drive as easily as you would control a normal CD player. Kit features a double sided PCB, pre-programmed micro controller, and IDC connectors for the display panel.



SMS Controller Module

KC-5400 £15.95 + post & packing

This kit will allow you to remotely control up to eight devices and monitor four digital inputs via an old Nokia handset such as the 5110, 6110, 3210, or 3310. Kit supplied with PCB, pre-programmed microcontroller and all electronics components with clear English instructions. Requires a Nokia data cable and handset.



Starship Enterprise Door Sound Emulator

KC-5423 £11.75 + post & packing

Refer to EPE June.

FOR ALL YOU TREKKIE FANS!

This easy to build kit emulates the unique sound of a cabin door opening or closing on the Star Ship Enterprise. The sound can be triggered by switch contacts or even fitted to automatic doors. Comes with PCB with overlay, speaker, case and all specified components. 9-12VDC regulated.

Micromitter Stereo FM Transmitter Kit

KC-5341 £15.95 + post & packing

This compact transmitter will connect to your CD or MP3 player and send your music to an FM radio anywhere in your house. Crystal locked to a preselected frequency to eliminate drift. Supplied with revised PCB with solder mask and overlay, case, silk screened lid and all electronic components. Some surface mounting soldering required.

50MHz Frequency Meter Mk II

KC-5440 £20.50 + post & packing

This compact, low cost 50MHZ Frequency Meter is invaluable for servicing and diagnostic work. Kit includes PCB with overlay, enclosure, LCD and all electronic components.

Features include:

- 8 digit reading (LCD)
- Prescaler switch
- Autoranging Hz, kHz or MHz

High Performance Timer

KC-5379 £12.95 + post & packing

This sophisticated timer can be used as a 'one shot' for turbo timers & thermo-fans etc. or as a 'pulse' timer to squirt a water spray for 1 second every 9 seconds for emergency cooling etc. The time is adjusted via easy to use digital switches. Kit supplied with PCB, and all electronic components with clear English instructions.

Clock Watchers Clock Kit with Blue LEDS

KC-5416 £55.25 + post & packing

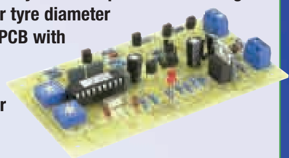
This facinating unit consists of an AVR driven clock circuit, and produces a dazzling display with 60 blue LEDs around the perimeter. It looks amazing, and can be seen in action on our website. Kit supplied with double sided silk screened plated through hole PCB and all board components as well as the special clock housing. Red display also available KC-5404 £41.75

Car Kits

Speedo Corrector MkII

KC-5435 £14.50 + post & packing

This kit alters the digital speedometer signal up or down by up to 99% and allows you to compensate for changes to gear & diff ratios, or tyre diameter etc. Kit supplied with PCB with overlay and all electronic components with clear English instructions.



Digital Fuel Mixture Display

KC-5300 £19.95 + post & packing

This brilliant dashboard-mounting unit monitors and displays your car's air-fuel ratio in real time on a three-digit display as well as a bargraph for readings at a glance. See our website for full details. Kit includes case with silk-screened panel, PCBs, pre-programmed PIC micro, 7-segment displays, red acrylic, hook-up wire and all electronic components.

Economy Adjustable Temperature Switch

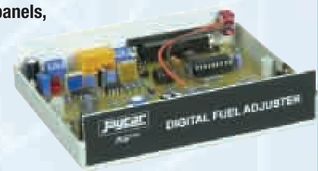
KC-5381 £9.75 + post & packing

It has an adjustable switching temperature (up to 245°C) and can be configured to trigger on rising or falling temperature. Useful for running cooling fans or over-temp warning lights or alarms, etc. Kit supplied with PCB, NTC Thermistor, and all electronic components.

Digital Fuel Adjuster

KC-5385 £25.95 + post & packing

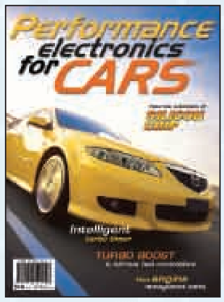
This unit gives you complete control of the air/fuel ratio at 128 points across the entire engine load range and provides incredible mapping resolution and brilliant drivability. It uses the Handheld Digital Controller - KC-5386 (available separately) so there is no need for a laptop. Supports both static and real-time mapping. Kit supplied with a quality solder masked PCB with overlay, machined case with processed panels, programmed micro and all electronic components.



High Performance Electronic Projects for Cars Book

BS-5080 £7.00 + post & packing

A fantastic range of 16 projects for performance cars ranging from devices for remapping fuel curves, to nitrous controllers. The book includes all instructions, components lists, colour pictures, and circuit layouts. All the projects are available in kit form, exclusively to Jaycar. Check out our website for all the details. Over 150 pages!



More Information? Secure Ordering?

www.jaycarelectronics.co.uk

UNIQUE TOOLS & ACCESSORIES

This is just a small selection from our massive range of hobbyist tools and accessories. See our website for our full range.

Auto Current Tester

QP-2251 £8.50 + postage & packing

This handy test unit makes it so easy to measure currents on individual circuits. Simply plugs into any standard blade type fuseholder and provides an easy-to-read LCD of the circuit's current draw. Measures up to 20A.

CAT III Auto-Ranging Pocket DMM

QM-1542 £14.00 + postage & packing

An advanced pocket sized DMM that is suitable for serious work. It features capacitance and frequency ranges as well as a CATIII rating and non-contact voltage detection.

- AC & DC voltage: 600V
- AC & DC current: 200mA
- Resistance: 40MOhms
- Capacitance: 100µF
- Frequency: 100kHz
- Diode & Continuity test
- Just 120mm long

Micro Magnifier with LED

QM-3531 £2.25 + postage & packing

Having trouble reading a street directory at night or a menu is a dimly lit restaurant? This pocket-size magnifier with super bright LEDs allows you to work or read anywhere and comes complete with a soft pouch for easy storage. Ideal to take travelling or camping.

- 2 Super bright white LEDs
- 3 X magnification with super 5 X magnifier
- Dimensions: 90(H) x 58(W) x 6(D)mm

Self Amalgamating Tape

NM-2826 £5.75 + postage & packing

Quality NITTO brand self fusing Butyl Rubber tape that will cure to a single mass when applied to wires, cables etc. Great for insulating and waterproofing etc. 20mm x 10mtrs

100 pc Driver Bit Set

TD-2038 £4.75 + postage & packing

This must be the ultimate driver bit set. It includes just about every type of bit you could imagine - even one for wing nuts!

Digital Tyre Pressure Gauge

GG-2310 £5.75 + postage & packing

Incorrect tyre pressures can cause adverse affects on handling and stopping distance and can also cause uneven or premature wear. This simple unit lets you monitor your tyre pressure simply and easily. Also includes an integrated torch and keychain attachment.

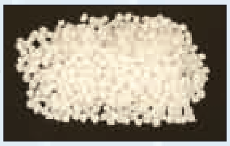
- Range: 0 - 150PSI.
- 90mm long

Polymorph Pellets

NP-4260 £3.00 + postage & packing

Heat the pellets in hot water and mould it to any shape. It hardens at room temperature to form a tough plastic material similar to Nylon. It can be machined or heated and reformed again and again. Endless uses: model making, craft, prototyping, engineering, science, lab etc.

Supplied in a 100g bag of 3mm pellets.



Aluminium Foil Tape - 50mm

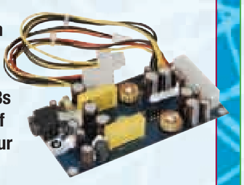
NM-2860 £4.25 + postage & packing

To be used in any number of situations including metal patching and general sealing.

12 Volt ATX Computer Power Supply for Cars

XC-4876 £27.75 + postage & packing

Simply replace the existing ATX power supply in your computer with this 12 volt DC version and you can run a PC in your car as an entertainment centre to store and play an almost limitless number of MP3s and MP4 movies etc. Add one of our TFT display screens and your car computer is ready to go.



Resistance Wheel

RR-0700 £5.75 + postage & packing

Great for experiments or selecting the best resistance for a circuit. Choose from 36 x 0.25W 5% resistors ranging from 5 ohms to 1M ohms. Comes complete with leads and insulated crocodile clips.

SEE OUR LATEST CATALOGUE FOR MORE EXCITING KITS & HOBBYIST EQUIPMENT

Starter Projects & Tools

Component Lead Forming Tool

TH-1810 £2.00 + postage & packing

This handy forming tool provides uniform hole spacing from 10 to 38mm. Made in USA from engineering plastic.

- 138mm long

Pin Extractor Press

TH-2014 £3.00 + postage & packing

A handy little pin-extractor/inserter press with a 0.8mm punch. Mainly intended for taking links out of watch bands, but endless other uses for jewellery making, model making and hobbies.

- 2 spare pin punches
- Assortment of 12 pins

Screwdriver Helper

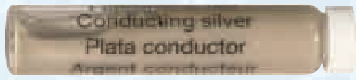
NM-2830 £4.00 + postage & packing

Dramatically increases the amount of torque you can apply to a damaged screw. Just apply a drop or two of Screwdriver Helper to instantly help remove or tighten screws with damaged heads.

Silver Conductive Varnish

NS-3030 £2.95 + postage & packing

Repairs printed circuits, window antennas, window alarm loops etc. Very good conducting properties. Approximately 0.02 - 0.1 ohms/cm².



Wire Glue 9ml

NM-2831 £2.75 + postage & packing

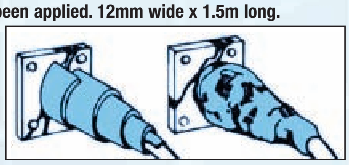
A conductive adhesive that enables you to make solder-free connections when you aren't able to solder. Hundreds of hobby, trade and electronics uses. Lead-free, cures overnight.

- 9ml

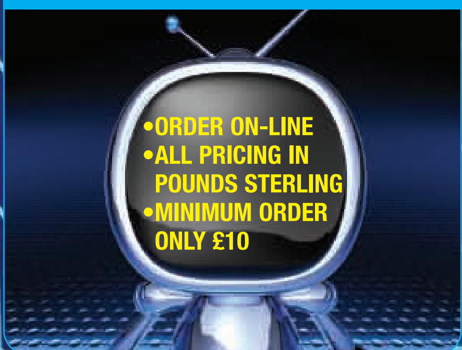
Coax Seal Tape

NM-2828 £3.00 + postage & packing

This versatile material looks like ordinary PVC electrical tape but is actually a handy sealing system that fuses together to form a removable, waterproof seal once it has been applied. 12mm wide x 1.5m long.



How To Order



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£50 - £99.99	£10	£500+	£40
£100 - £199.99	£20		

Max weight 12lb (5kg). Heavier parcels POA.
Minimum order £10.

Note: Products are despatched from Australia, so local customs duty and taxes may apply.

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Call Australian Eastern Standard Time Mon-Fri
Phone: 0800 032 7241
Fax: +61 2 8832 3118
Email: techstore@jaycarelectronics.co.uk
Post: P.O. Box 107, Rydalmere NSW 2116 Australia
Expect 10-14 days for air parcel delivery

Check out the Jaycar range in your FREE Catalogue - logon to **www.jaycarelectronics.co.uk/catalogue**

or check out the range at **www.jaycarelectronics.co.uk**

0800 032 7241

(Monday - Friday 09.00 to 17.30 GMT + 10 hours only)
For those who want to write: P.O. Box 107 Rydalmere NSW 2116 Sydney AUSTRALIA

Jaycar Electronics

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4021B	£0.31
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4024B	£0.22
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4026B	£0.67
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4028B	£0.21
4029B	£0.38
4030B	£0.17
4035B	£0.31
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4063B	£0.41
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4069UB	£0.18
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4093B	£0.16
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4515B	£0.99
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4518B	£0.26
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74HC126	£0.46
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74HC595	£0.27
74HC597	£0.22
74HC688	£0.46
74HC4002	£0.31
74HC4017	£0.36
74HC4020	£0.36
74HC4040	£0.29
74HC4049	£0.31
74HC4051	£0.50
74HC4052	£0.34
74HC4053	£0.23
74HC4060	£0.23
74HC4075	£0.27
74HC4078	£0.22
74HC4511	£0.64
74HC4514	£0.84
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74LS03	£0.21
74LS04	£0.30
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74LS221	£0.41
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LM13700	£1.35
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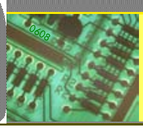

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You get what you pay for

EPE is not a consumer magazine, but through news and columns such as *Net Work* and *Techno Talk* we do try and keep you abreast of some of the more relevant trends – and pitfalls – in areas related to our hobby.

I'm sure you've noticed that over the past few issues we've had some useful warnings from Alan Winstanley about the perils of cheap-rate ISPs and the poor service some of them provide. I expect many of you have had similar experiences of superficially good budget deals becoming less attractive once things go wrong and you try to get some proper phone support. There's something extraordinarily frustrating about poor call centre support, whether it's the dozen or so numbers you have to enter to 'ensure your call is most efficiently directed' or the depressingly predictable message that 'some calls are recorded for training purposes'; deep down we know that we'll be stuck in a queue and probably give up, only to start the whole sorry business all over again ten minutes later. We've all been there, and it really is psychological torture!

Consumers have got so used to price/speed being the sole determinant in choosing ISPs that it is hard to imagine paying a bit more for 'proper' service. However, from personal experience I've noticed a number of changes in recent months; so maybe the market is starting to change. My own ISP (Virgin – formerly NTL) provides a mostly good service, but I still call them a couple of times a year with service loss issues. Originally, NTL provided free, often well-informed, but hard-to-access support. Under Virgin, I felt the service initially degenerated – and it was no longer free – which really was the worst of both worlds. To be fair though, I've noticed the last few calls have been dealt with much more efficiently, and now if the fault lies with Virgin then the call is free. Virgin aren't the cheapest, but I'm happy to pay a bit more and keep my blood pressure under control.

It's not just ISPs who are beginning to realise that service matters. eBay, which for years was almost invisible in terms of real support, now offers a support line (020 8080 2105). I hope these small pieces of evidence are the start of a more general trend, where for a reasonable fee, either directly charged, or in the case of eBay through their sales charges, internet-based services will become more customer friendly.

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All reasonable precautions are taken to ensure that the advice and data given to readers is reliable. We cannot, however, guarantee it and we cannot accept legal responsibility for it.
A number of projects and circuits published in *EPE* employ voltages that can be lethal. **You should not build, test, modify or renovate any item of mains-powered equipment unless you fully understand the safety aspects involved and you use an RCD adaptor.**

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We advise readers that certain items of radio transmitting and telephone equipment which may be advertised in our pages cannot be legally used in the UK. Readers should check the law before buying any transmitting or telephone equipment, as a fine, confiscation of equipment and/or imprisonment can result from illegal use or ownership. The laws vary from country to country; readers should check local laws.

News . . .

A roundup of the latest Everyday News from the world of electronics

DIGISCOPING

Barry Fox reports on how to make use of redundant digital camera equipment

A RECENT wildlife photography exhibition sponsored by Nikon had a special section for *digiscoping*. For hands-on experimenters, like *EPE* readers, digiscoping is a great way to avoid throwing away perfectly good digital camera equipment that has been relegated to the cupboard when a new camera came along.

The idea of digiscoping came from birdwatchers, who often use a high magnification telescope – 20× or 30× – on a tripod to get a close look at a distant nest or perch. Someone tried putting a camera up against the scope, so that it 'looked' through the scope. They got a very powerful telephoto effect.

Manufacturers – notably Nikon – that make both cameras and scopes now sell kits that neatly bolt them together. But most people will have to make some kind of mounting bar to screw onto a tripod and connect a camera and scope of different brands. The magnification available can be mind-blowing. But there are several tricks experimenters need to know.

In the picture

If the scope has a zoom lens it should be set to around 20×, not much greater. The camera lens must be very, very close to the eyepiece lens of the scope – ideally only a hair's breadth away. Also the camera should be zoomed to its maximum telephoto setting eg 3×, so that it is 'seeing' through only the centre part of the scope eyepiece. If this not done, the result is *vignetting*; the image is a circle of light in the centre of the picture.

Ideally, the camera should have a zoom lens that does not physically move backwards and forwards; ie only the elements inside the lens move. This makes it much easier to lock the camera close to the scope without any risk of physically cracking the lens glass when the camera is zoomed to maximum magnification.

The mount must be very strong and rigid, because the combined magnification of a 3× camera zoom and 20× scope is 60×, and even the slightest vibration will make the image shake wildly. For this reason, some kind of mechanical or electrical remote control for the shoot button is essential; even the slightest finger pressure will cause massive image shake. The tripod must be very solid too, for the same reason.

Modern interest in digiscoping reminds me of an adage from the old days of 8mm home cinematography; the most useful and cost effective accessory that a movie photographer can ever buy is a tripod. Shooting movie cine or camcorder video with a handheld camera and long focus lens is a sure way to make the results look amateur. Shooting from a tripod is the first step towards making home movies look professional.

New low-cost, general-purpose 8-bit PICs

Microchip has announced a new family of low-cost 8-bit Flash PIC microcontrollers (MCUs). The 28 and 40-pin PIC16F722/3/4/6/7 MCUs are capable of operation down to 1.8V and feature a 16MHz internal oscillator; up to 14 analogue-to-digital converter (ADC) channels; communication peripherals (SPI, 12CTM, AUSART); two capture, compare and PWM (CCP) modules; and the mTouch Sensing Solution peripheral.

The PIC16F72X MCUs have an operating voltage range of 1.8 to 5.5V, with the lowpower PIC16LF72X devices offering even lower standby and other power-consumption specifications from 1.8 to 3.6V. All the new devices feature a Timer Gate that runs from the internal 16MHz oscillator, providing ease in conditional event counting and measurements.

The mTouch Sensing Solution peripheral makes it easy to add proximity sensing or capacitive touch-sensing user interfaces in place of mechanical buttons or switches, if designers so choose. Additionally, the mTouch peripheral can operate while the device is in sleep mode, bringing further power savings to the user.

The new MCUs have integrated in-circuit debug and are supported by the free MPLAB Integrated Development Environment. MPLAB REAL ICE in-circuit emulator support is expected to be available in the fourth quarter of 2008.

General sampling and volume production is available at **sample.microchip.com** and **www.microchipdirect.com**, respectively.

For further information, visit Microchip's web site at **www.microchip.com/startnow**.

TEMPERATURE LOGGING

AREXX Engineering from The Netherlands claims to be the European market leader in designing, manufacturing and marketing educational robotics. AREXX also develops non-robotic products. In close cooperation with Havinga Software, one of the latest developments is the revolutionary TL-500 temperature logging system.

The TL-500 system can be used for indoor and outdoor locations, everywhere where a registration of temperature information is needed. It even works in many freezers and refrigerators. You can also use it in your house: living room, baby's room, refrigerator, or garage, etc. It is the perfect tool for long term registration of the course of temperatures at different locations.

The temperature logging system includes a wireless USB 2.0 BS-500 base station (433MHz) and two wireless TL-3TSN temperature sensors (also separately available). Furthermore, a USB cable, a CD-ROM with temperature logging software for MS Windows 98SE/Me/2000/XP/Vista/XP64 and Vista64, a screensaver and messenger software for email messages are supplied.

Three very important features of the TL-500 are: up to 50 sensors can be connected to the system.

Different wireless sensors are separately available. New sensors that are under development, including a CO_2 sensor and a professional waterproof sensor with a display and external probe. It includes a Messenger program.

The Messenger program is a userfriendly, extra feature. It enables the automatic forwarding of the temperature data to email addresses and dedicated webservers. With email-to-SMS service, it is even possible to send SMS warnings to your mobile phone.

Every 45 seconds, the TL-500 receives new temperature data all sensors and passes this information wirelessly on to the PC for further processing. For further processing the data, a visualisation program is at your disposal, which also enables data export to other programs.

The UK distributor is Rapid Electronics, **www.rapidonline.co.uk**.

For more information: email: info@arexx.nl, **www.arexx.com**.

Flowcode and E-blocks

Matrix Multimedia tell us that the new Flowcode for ARM adds considerable power to Flowcode, as it includes full floating point arithmetic and a full mathematics library, which considerably increases its usefulness as a development tool for engineering. The code on the ARM will run around 50 times faster than the code on a PICmicro. New anti-piracy features are built into this version of Flowcode, and all future versions. A demonstration version is available on the Matrix website. For a full datasheet see **www.matrixmultimedia.com/datasheets/TEFLC-60-3.pdf**.

A service pack for Flowcode V3 for PICmicro is now available as a free upgrade from the Matrix website. This includes support for a number of new systems, including Zigbee, RFID, Graphical LCD and extended CAN bus systems. For a full datasheet see **www.matrixmultimedia.com/datasheets/TEFLC-60-3.pdf**.

Flowcode Ultimate is a new version of Flowcode that combines Flowcode V3 for AVR, Flowcode V3 for PICmicro and Flowcode V3 for ARM. This is available to customers at a considerable discount to the sum of the retail prices. For a full datasheet see **www.matrixmultimedia.com/datasheets/TEFLC-60-3.pdf**.

All versions of Flowcode are now available in Japanese, Slovakian, Vietnamese and Korean. A full help file in Italian will shortly be available as a patch.

Matrix are now in the final phases of development of two new training solutions: RFID and Zigbee. Datasheets of these solutions can be seen at: **www.matrixmultimedia.com/datasheets/EB699-60-1.pdf** and **www.matrixmultimedia.com/data sheets/EB284-60-1.pdf**.

A new E-blocks board is available that allows those with PASCO type sensors to use them with E-blocks systems. For details: **www.matrixmultimedia.com/datasheets/EB052-30-1.pdf**.

An RFID board (shipped with sample tags) is now shipping. This allows rapid development of systems with RFID functionality. See: **www.matrixmultimedia.com/datasheets/EB054-30-1.pdf**.

A Zigbee wireless sensor network board is also shipping. See: **www.matrixmultimedia.com/datasheets/EB051-30-1.pdf**.

A number of new E-blocks bundles are available: Flowcode for ARM with E-blocks, Flowcode for AVR with E-blocks, Easy Zigbee pack, Easy RFID pack. See the Matrix website for details.

E-blocks has now received registered trade mark status, which will allow Matrix to protect the brand.

For more information on these products contact Matrix Multimedia Ltd, Dept *EPE*, The Factory, Emscote Street South, Halifax, W. Yorks, HX1 3AN. Web: **www.matrixmultimedia.com**. Tel: +44 (0)1422 252380. fax: +44 (0)1422 252381.

Inventor of first practical transistor dies

Morgan Sparks, a former director of Sandia National Laboratories, inventor of the first practical transistor died on Saturday May 3. He was 91 years old.

Sparks served as Sandia Labs director from 1972 until his retirement in 1981. Prior to Sandia, Sparks had a 30-year career with Bell Laboratories in New Jersey and is best remembered as the person who fashioned the first practical transistor.

Current Labs Director Tom Hunter says, "Morgan was president when I was a young staff member at Sandia. He set the framework for Sandia to become a multiprogram lab. He was widely recognised for his ability to engage the Labs in many new areas that proved to be important for our future."

PICO WARRANTY

Pico Technology, claimed to be worldwide leader in the design and manufacture of PC Oscilloscopes, has announced with immediate effect that it has increased the warranty period from two years to five years on its award-winning PicoScope 5000 Series oscilloscopes.

The huge buffer size (32 Msamples on the 5203, 128 Msamples on the 5204) and 1GS/s realtime sampling rate make the PicoScope 5000 Series an indispensable measurement and test instrument. The scope is supplied with the latest copy of the PicoScope 6 software.

According to Alan Tong, Managing Director of Pico Technology, "All our future customers can enjoy the peace of mind of knowing that their investment in the PicoScope 5000 Series is protected."

Full details on the PicoScope 5000 Series and PicoScope 6 software are available for download now from the Pico Technology website, or call Pico on +44 (0)1480 396 395 for more details.

PIC MIDI Wave Sound Generator

by Mike Rainbow

★Five octaves ★18 'instruments' ★Eight-note polyphony

MANY electronic gadgets, such as a mobile phone, PC, games console or synthesiser keyboard, have some sort of wavetable synthesis music generation source built in, the list is almost endless. Unfortunately, the integrated circuits used in these devices are not available to the ordinary hobbyist and after searching unsuccessfully for a suitable device or circuit for various musical projects over the years, the author decided to have a go at designing something himself.

The question was whether an acceptable quality musical instrument sound could be reproduced using 8-bit technology and whether it was possible to produce eight-note polyphony using inexpensive PIC's. The PIC MIDI Wave Sound Generator is the result of that quest.

As is common with microcontroller projects, the circuit design is quite straightforward, most of the clever work is done by the software. The author spent a weekend designing the circuit and about 18 months writing the software.

Wavetable synthesis

Wavetable synthesis, or more correctly, sample-based synthesis is a form of audio synthesis where the sound of real instruments is sampled as a digital waveform and played back at different rates to reproduce all the notes of a musical scale. These notes can be controlled directly by a music keyboard or if MIDI (Musical Instrument Digital Interface) is employed, just about any form of control can be used, limited only by the designer's imagination. The author has built various guitar-like MIDI controllers with great success.

Samples can be fairly short and artificially lengthened by looping through the same data samples over and over again. Fig.1 shows a wave sample with the loop points for electric guitar. Techniques such as cross-fading, interpolation and filtering are used to ensure that the final sound is as close to the original as possible.

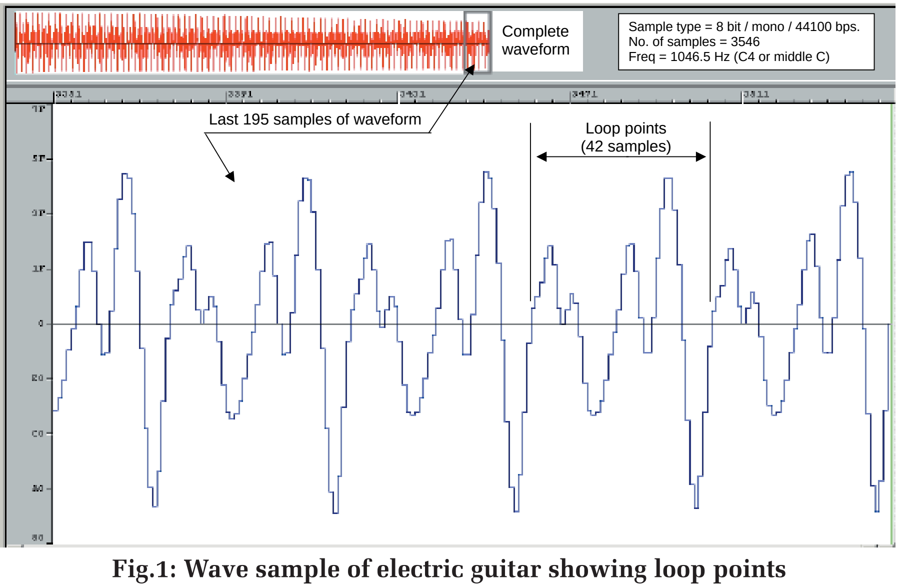


Fig.1: Wave sample of electric guitar showing loop points

A brief overview

In this project, the MIDI input is decoded and controls the wave sample generator, which retrieves instrument samples from an EEPROM (Electrically Erasable Programmable Read Only Memory). Fairly complex calculations then take place and the digital result is fed to a serial 12-bit DAC (digital-to-analogue converter). Finally, the audio output of the DAC is filtered and amplified to line and headphone levels.

Apart from the software problems, there was the question of how to obtain suitable sound samples without breaching royalty copyrights protecting samples used in commercial products. This was overcome by using 'home-made' samples for some instruments and adapting royalty-free samples found on the internet for other instruments.

Table 1: Accepted MIDI messages

General MIDI message format is 2 – 3 bytes long		
1 - Status byte	2 - Data byte	3 - Data byte
1mmmnnnn	0ddddddd	0ddddddd
1st bit always = 1 m = message type n = channel no.	1st bit always = 0 d = data	1st bit always = 0 d = data
Note on messages		
1st byte	2nd byte	3rd byte
10010000	0kkkkkkk	0vvvvvvv
note on / ch.1	k = key no. (0 – 127) (36 – 96 used)	v = velocity (0 – 127) (<65 = off, >64 = on)
Note off messages		
1st byte	2nd byte	3rd byte
10000000	0kkkkkkk	0vvvvvvv
note off / ch.1	k = key no. (0 – 127)	v = velocity (0 – 127) (always 0)
Control change messages (sustain on/off)		
1st byte	2nd byte	3rd byte
10110000	01000000	0vvvvvvv
ctl change / ch.1	sustain = 64	v = ctler value (<65 = off, >64 = on)
Program change messages (Instrument change)		
1st byte	2nd byte	3rd byte
11000000	0ppppppp	no byte transmitted.
pgm change / ch.1	p = instr. no. (0 – 127)	
(PIC program will select nearest instrument sound from 28 on EEPROM.)		

Features

The main features of the MIDI Wave Sound Generator and instruments available are:

- **MIDI input**
- **Five octaves (C2 to C7)**
- **Eight-note polyphony**
- **18 wave table instruments on a 512k flash EEPROM**
- **Audio line and headphone output**
- **Accepts note on/off, instrument change and sustain on/off MIDI messages on Channel 1. Table 1 shows details of accepted MIDI messages**

MIDI Instruments

Instrument	MIDI Inst No.
1. Acoustic Piano	01
2. Honky Tonk Piano	04
3. Elec. Piano 1	05
4. Elec. Piano 2	06
5. Harpsichord	07
6. Vibraphone	12
7. Organ 1	17
8. Organ 2	19
9. Organ 3	20
10. Nylon Guitar	25
11. Steel Guitar	26
12. Elec. Guitar	28
13. Overdriven Guitar	30
14. Synth. Guitar	85
15. Banjo	106
16. Strings	49
17. Synth. Strings	51
18. Trumpet	57

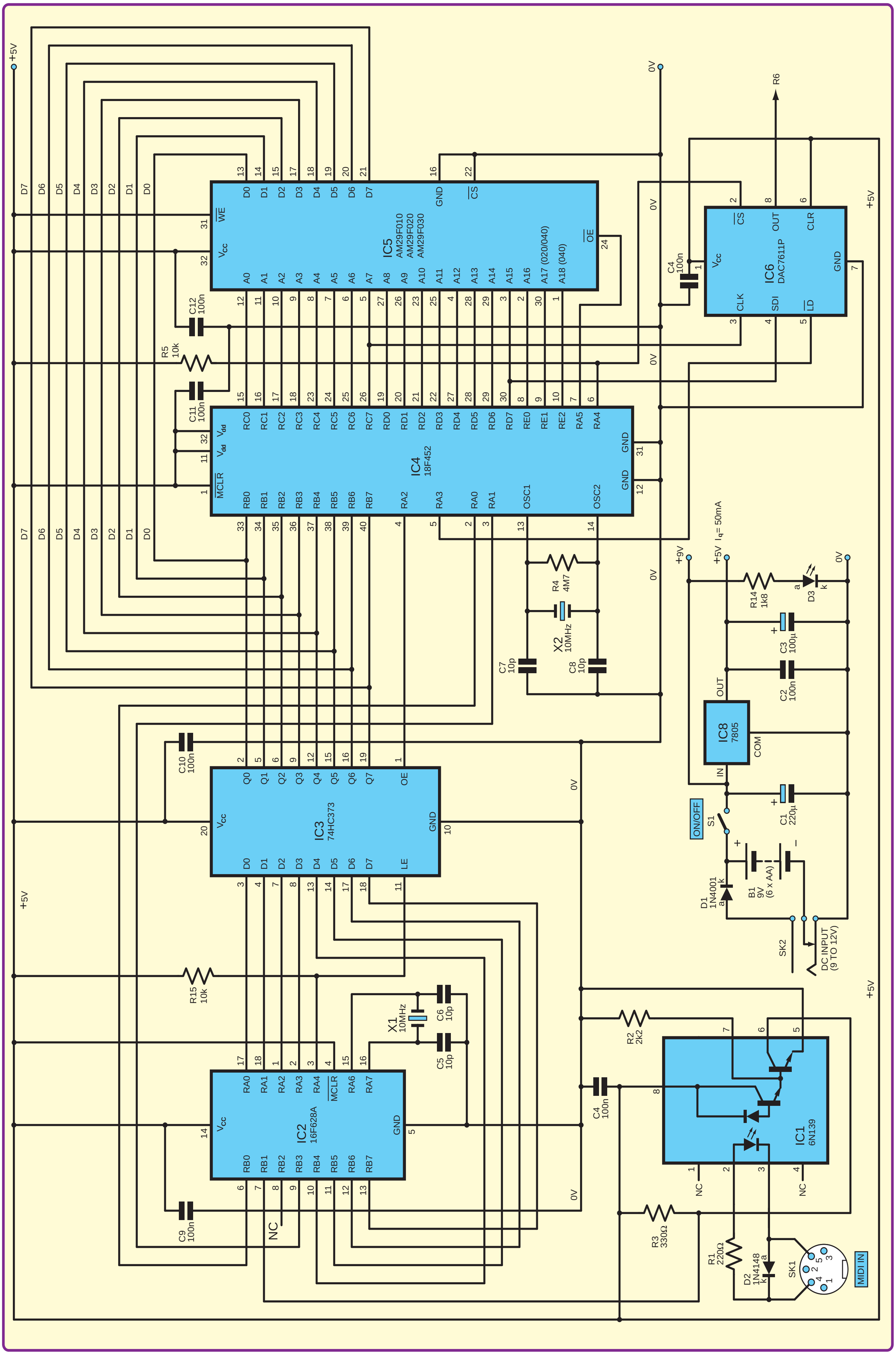


Fig.2: The two circuit diagrams (one opposite) that make up the complete circuit for the PIC MIDI Wave Sound Generator

Instrument samples were recorded as **.wav** files on a PC and the wave data was then edited and reformatted to be included in a final file stored on a flash EEPROM.

Circuit description

The complete circuit diagram of the MIDI Wave Sound Generator is shown in Fig.2. MIDI messages coming in from the 5-pin DIN socket (SK1) arrive at opto-isolator IC1, at pins 2 and 3. The 6N139 opto-isolator ensures there are no earth-loop problems with the equipment that may be connected to the MIDI input. The output from pin 6 is then fed to the USART (universal synchronous asynchronous receiver transmitter) receive pin, RB1 of IC2, a 16F628A PIC running at 10MHz, set by crystal X1.

The USART built in to the 16F628A is set up to receive serial 10-bit MIDI bytes, that is a start bit, eight data bits and a stop bit, at the standard MIDI rate of 31250 bits/second. Fortunately, the PIC's USART is designed to do most of the hard work for us, so all we have to worry about is analysing and interpreting the MIDI messages which are comprised of 2 or 3 MIDI bytes each.

IC2's software discards irrelevant MIDI messages and separates the messages we are interested in. These can be control messages, which are instrument change or sustain on/off messages, or note on/off messages, which are allocated channels (not to be confused with MIDI channels) 1 to 8, to be used in the sound generator section of the circuit.

Sound generation

The control and note information generated by IC2 is in a similar form to the general MIDI format, but is stored as two 8-bit bytes and transferred one at a time into IC3, an 8-bit data latch. Four pins of port A and four pins of port B are used to accomplish this.

Port RA4 on IC2 is used to enable the latch input (pin 11) on IC3, and RB0/RB3 are used to tell the sound generator, IC4, which of the two bytes are ready to be read or whether to reset and prepare to receive two new bytes. When the sound generator (IC4) is ready, these two bytes are loaded from the latch output onto the common data lines, D0 to D7 controlled by RA2 on IC4.

IC4 is a 18F452 PIC running at 40MHz. You will notice that crystal X2 is 10MHz, but the PIC's internal PLL (phase-locked loop) is configured to multiply the crystal frequency up to the higher rate.

This is necessary to be able to get through as much code as possible during the 90.7μs available in the program main loop before the output information needs to be updated. This is a result of deciding on a minimum sample rate of 11025 samples/second to obtain a reasonable sound quality (1/11025 = 90.7μs).

Every possible programming trick was used to squeeze as much code as possible into this requirement. At 40MHz, this meant there were 907 instruction cycles available for the main program loop code. Not a lot for the eight-note polyphony target (this means being able to play eight notes simultaneously).

Port B of IC4 is used to receive data from the latch IC3 and from the EEPROM IC5. Port RA2 on IC4 enables the output latch, IC3's pin 1. Port C, D and E of IC4 are used to address up to 512kB of 8-bit sample data on the Flash EEPROM, IC5.

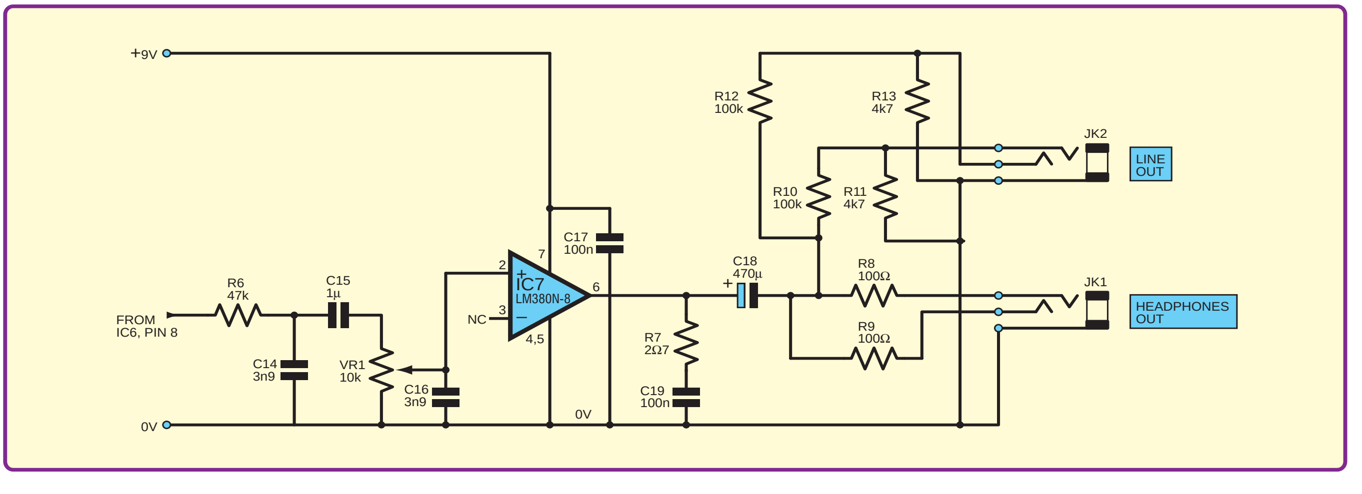
In this circuit the EEPROM can be either a 128kB (128k x 8-bit), 256kB or 512kB device, with no changes to the hardware and only minor changes to the software. The author used a 512kB device, even though only half the memory was utilised, as there is very little difference in the prices of the three types and this allows for additional instrument samples in the future. Port RA5 is used to control the output enable pin of the EEPROM.

Up to eight note samples are processed and added together to make an 11-bit final data sample, which is fed, a bit at a time to a 12-bit DAC (IC6). Theoretically, this means that there is spare capacity in the DAC to handle an additional eight notes, but this would require doubling the amount of code in the main program loop. Some genius out there may be able to achieve this, but the author has failed so far.

One of the address lines, RD7 of IC4, doubles up as the serial data output to the DAC input on pin 4. Another address line, RC7 of IC4, is used to clock the DAC on pin 3 and RA3 toggles the DAC data load pin, pin 5. The chip select pin (2) of IC6 is controlled by port RA4 of IC4, which is an open drain output, so it requires load resistor R5.

The audio output from the DAC, pin 8, is filtered to remove the 11.025kHz sampling component by a simple low-pass filter formed by R6, C14, C15 and VR1. Finally, the composite audio signal is amplified to line and headphone level by IC7, a LM380N-8. It is an 8-pin version of the popular 2W audio amplifier. This device is capable of driving an 8Ω speaker, but in this circuit it drives low impedance headphones as well as the line output.

The stereo headphone jack socket (JK1) is fed by two 100Ω resistors in such a way that if either a mono or stereo headphone jack is plugged in, both types will work equally well. In much the same way, the line output signal is obtained from two attenuators,



R10/R11 and R12/R13 and fed to a stereo socket (JK2) to allow for either stereo or mono cables. RC network R7 and C19 is there to prevent high frequency instability in IC7.

Power supply

The power supply is straight forward and provides an unregulated +9V DC to the audio amplifier (IC7) as well as a regulated 5V DC from IC8 (a 7805) to the rest of the circuit. The 50mA total quiescent current required means that six 1.5 volt AA batteries are quite adequate to power the circuit, or a 9V regulated DC power adaptor may be used. LED D3 and resistor R14, mounted on the front panel, have been added for power On indication.

If using an external power supply, it is essential that you use a *regulated* DC supply with a voltage output of between 9V and 12V, and a current rating of at least 300mA. An unregulated supply produces an unacceptable level of mains hum on the audio output. Fortunately, regulated power adaptors are now virtually the same price as unregulated ones, so this is no great expense.

Wave sampling in brief

Using a sample rate of 44.1kB/s, a single digital sample of each instrument was made or obtained and, using a PC wave editor program, the samples were adjusted to a frequency of *C4* (middle *C* on the piano). These samples were then edited to tidy them up and frequency quadrupled to *C6*. Playing back these *C6* samples at 11.025 kB/s (a quarter of the recorded sample rate) brings the samples back to *C4*.

This is called over-sampling and gives us loads of extra samples to work with when changing note frequencies to represent all twelve notes in a scale. After working out and noting the data start, end and loop points in each sample, hex files were made to store all this information on the EEPROM. Table 2 shows the file format used on the EEPROM.

The sample data consists of 8-bit numbers with values from 0 to 255. These numbers represent voltage amplitude values of the sampled waveform, which has positive and negative values about a zero voltage base line. 128 is used as the zero base line, so that values of from +127 to –128 can be used to represent the positive and negative values of the sample waveform. This also makes it easier to add eight different note samples together.

General positioning of components inside the low-profile case

Since the instrument samples are all at middle *C*, we have to find a way of changing the frequency of the samples to simulate all the notes from *C2* to *C7*, 61 in total. Table 3 shows all the notes with frequencies and MIDI note numbers. This is done by stepping through the samples at different rates.

If we step through the samples one at a time, we get middle *C* or *C4*. If we step through missing every second sample, we will effectively get twice the frequency or

Table 2: EEPROM File Format

EEPROM Header

Hex Add.	Dec Add.	Data	Bytes
0000h	0 - 19	Rainbow Electronics	20
0014h	20	<no. of instruments>	1
0015h	21 - 23	1st instr.start address	3
0024h	24 - 26	2nd instr.start address	3
↓	↓	↓	
005Ah	90 - 92	24th instr.start addr.	3
	up to 255	(so 1 byte only for pointer in PIC code)	
0100h	256 -	Start of 1st instr. sample	

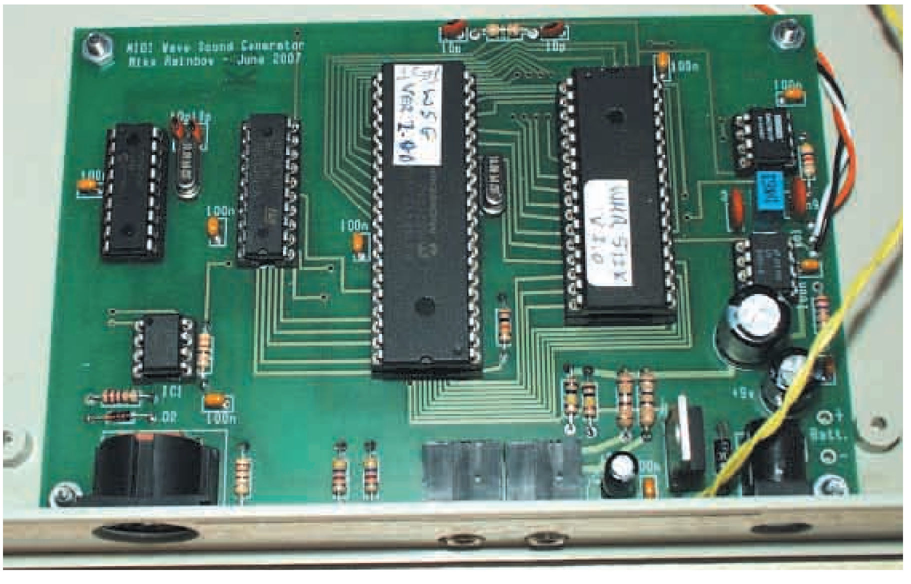
Wave File Header

Dec Add.	Data	Type	Bytes
0 - 3	Header name ("wmr.")	asc	4
4	Instr. number	hex	1
5 - 15	Instr. name	asc	11
16 - 17	Loop end addr.(up to 64k)	hex	2
18 - 19	Loop start addr.	hex	2
20	Perc.(2) or non-perc.(0)	hex	1
21	GM midi instr. Number	hex	1
21 - 35	spare		15
36 - 39	Data identifier ("data")	asc	4
40 - 64k	Wave sample data	hex	

NOTES:
1. Numbers are msb first.
2. Addresses always within 64k block.
3. All addresses relative to 0 (ie first sample) not +40 (ie. instr. start address).

Table 3: Notes with frequencies and MIDI note numbers

Note	MIDI No.	Freq. (Hz)	Note	MIDI No.	Freq. (Hz)
C2	36	65.41	G4	67	392.00
C#2/Db2	37	69.30	G#4/Ab4	68	415.30
D2	38	73.42	A4	69	440.00
D#2/Eb2	39	77.78	A#4/Bb4	70	466.16
E2	40	82.41	B4	71	493.88
F2	41	87.31	C5	72	523.25
F#2/Gb2	42	92.50	C#5/Db5	73	554.37
G2	43	98.00	D5	74	587.33
G#2/Ab2	44	103.83	D#5/Eb5	75	622.25
A2	45	110.00	E5	76	659.26
A#2/Bb2	46	116.54	F5	77	698.46
B2	47	123.47	F#5/Gb5	78	739.99
C3	48	130.81	G5	79	783.99
C#3/Db3	49	138.59	G#5/Ab5	80	830.61
D3	50	146.83	A5	81	880.00
D#3/Eb3	51	155.56	A#5/Bb5	82	932.33
E3	52	164.81	B5	83	987.77
F3	53	174.61	C6	84	1046.50
F#3/Gb3	54	185.00	C#6/Db6	85	1108.73
G3	55	196.00	D6	86	1174.66
G#3/Ab3	56	207.65	D#6/Eb6	87	1244.51
A3	57	220.00	E6	88	1318.51
A#3Bb3	58	233.08	F6	89	1396.91
B3	59	246.94	F#6/Gb6	90	1479.98
C4	60	261.63	G6	91	1567.98
C#4/Db3	61	277.18	G#6/Ab6	92	1661.22
D4	62	293.66	A6	93	1760.00
D#4/Eb4	63	311.13	A#6/Bb6	94	1864.66
E4	64	329.63	B6	95	1975.53
F4	65	349.23	C7	96	2093.00
F#4/Gb4	66	369.99			



C5. Every fourth one will give us *C6* and every eighth one gives us *C7*.

To get octaves below *C4*, ie *C3* and *C2*, and to get the 11 other semitones is slightly trickier and involves stepping in fractions as well as whole numbers. This is achieved by using look-up tables and interpolation techniques.

The samples are relatively short in duration, between 2kB and 12kB. This represents actual time periods of about 180ms to one second, so the usual method of extending a note indefinitely is to choose a loop section of the waveform and go through it as many times as is necessary. In the case of percussive instruments, such as piano and guitar, the loop also has to decay over time. Artificially decaying the sample wave is also used to simulate sustain, but at a different decay rate.

Loop selection

Selecting the loop points is a science/art in itself, and requires a bit of patience and practice. If you get it wrong you will hear a 'click' during the loop transition points. Using special techniques, such as cross-fading, can help greatly and it's worth pointing out here that all PC programs used by the author for editing and storing samples are available as freeware on the internet.

Another problem to overcome at these relatively low sample rates is aliasing, which occurs when the sample frequency or harmonics in the sample are greater than half the sample rate. The result of aliasing is unwanted frequency components, which are very unpleasant to the human ear.

The highest note, *C7*, whose fundamental frequency is about 2093Hz, is well below the maximum permissible 5512.5Hz (this is half the sample rate of 11025Hz), but the very nature of musical instrument sounds and what makes them different from each other is their harmonic content. A flute has a very pure sound, composed mainly of the fundamental frequency of the note, whereas the sound from a harpsichord is full of harmonics, causing major aliasing problems in the higher notes.

This effect can be minimised by low-pass filtering of the sample waveform, which can be done easily in the wave editor program before loading the samples into the EEPROM. However, great care must be taken to avoid reducing the sound to a dull unrecognisable reproduction of the original.

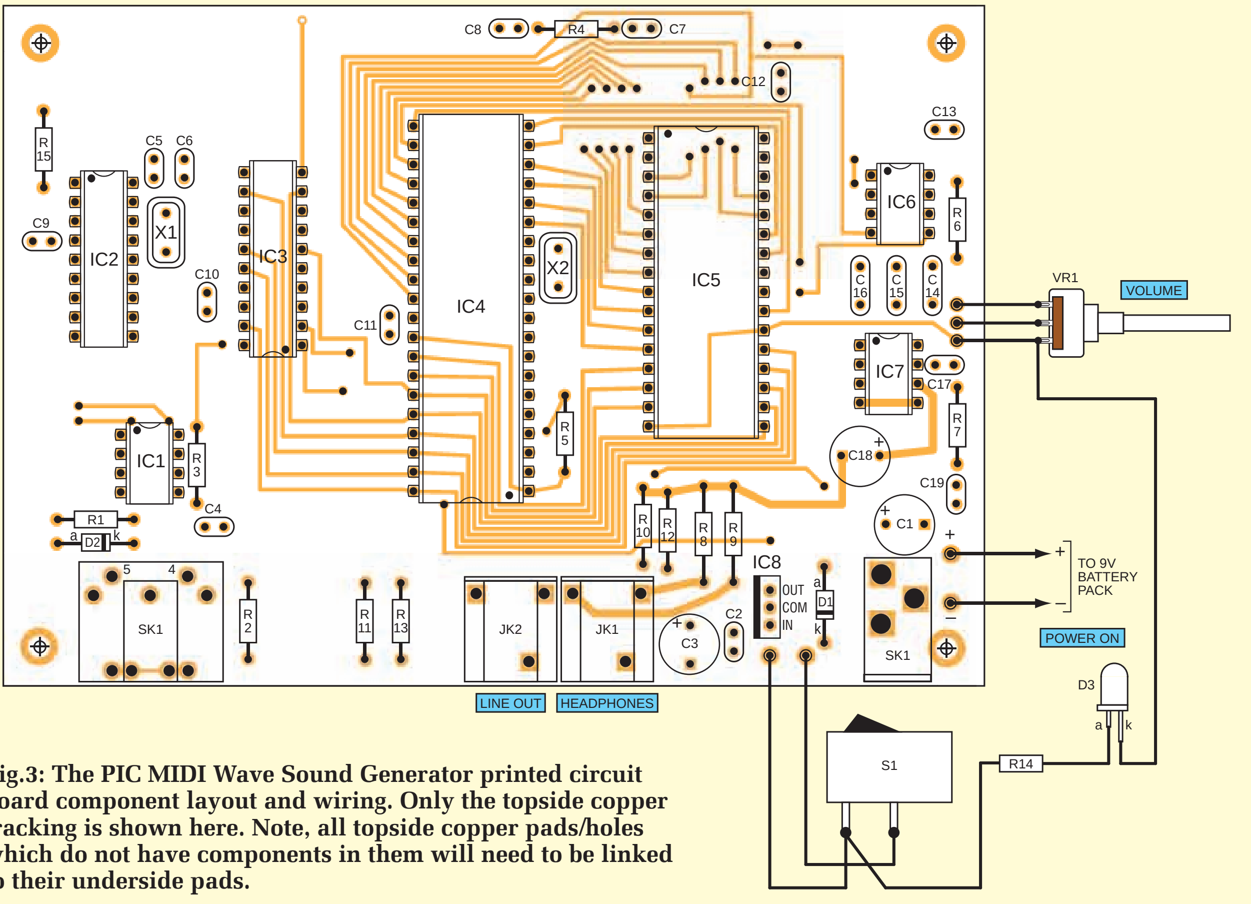


Fig.3: The PIC MIDI Wave Sound Generator printed circuit board component layout and wiring. Only the topside copper tracking is shown here. Note, all topside copper pads/holes which do not have components in them will need to be linked to their underside pads.

Parts List – PIC MIDI Wave Sound Generator

1 PC board (double-sided), Code 672, available from the *EPE PCB Service*, size 130mm × 90mm
1 ABS low-profile instrument case, size 190mm x 140mm x 30mm
1 Min. SPST toggle or rocket switch (S1)
1 5-pin 180 deg. DIN socket, PCB mounting (SK1)
1 2.1mm DC power input socket, PCB mounting (SK2)
2 3.5mm stereo jack sockets, PCB mounting (JK1, JK2)
3 8-pin DIL sockets
1 18-pin DIL socket
1 20-pin DIL socket
1 32-pin DIL socket
1 40-pin DIL socket

Multistrand connecting wire; plastic knob; PCB supports; 9V battery and clip (if used); solder pins; solder etc.

Semiconductors
1 1N4007 1000V 1A rect. doide (D1)
1 1N4148 signal diode (D2)
1 5mm red LED and lens (D3)
1 6N139 split-Darlington opto-isolator (IC1)
1 *PIC16F628A microcontroller, preprogrammed (IC2)
1 74HC373 octal D-type latch (IC3)
1 *PIC18F452 microcontroller, preprogrammed (IC4)
1 *AM29F040 Flash EEPROM, preprogrammed (IC5)
1 DAC7611P 12-bit serial DAC (IC6)
1 LM380N-8 audio power amp. (8-pin version)(IC7)
1 LM7805 +5V 1A voltage regulator (IC8)
2 10MHz crystals (X1, X2)

Capacitors
4 10pF ceramic (C5, C8)
2 3n9 ceramic, 50V (C14, C16)
9 100nF ceramic, 50V (C2, C4, C9 to C13, C17, C19)
1 1µF ceramic, 50V (C15)
1 100µF radial elect. 25V (C3)
1 220µF radial elect. 25V (C1)
1 470µF radial elect. 25V (C18)

Resistors (0.25W, 1% carbon, except R8, R9)
1 2Ω7 (R7)
2 100Ω 0.5W (R8, R9)
1 220Ω (R1)
1 330Ω (R3)
1 1k8 (R14)
1 2k2 (R2)
2 4k7 (R11, R13)
2 10kΩ (R5, R15)
1 47kΩ (R6)
2 100kΩ (R10, R12)
1 10M7 (R4)
1 10kΩ rotary carbon potentiometer, log. (VR1)

*Preprogrammed chips are available from Mike Rainbow – Email: **mrainbow@rainbowelectronics.co.uk** also see **www.rainbowelectronics.co.uk**

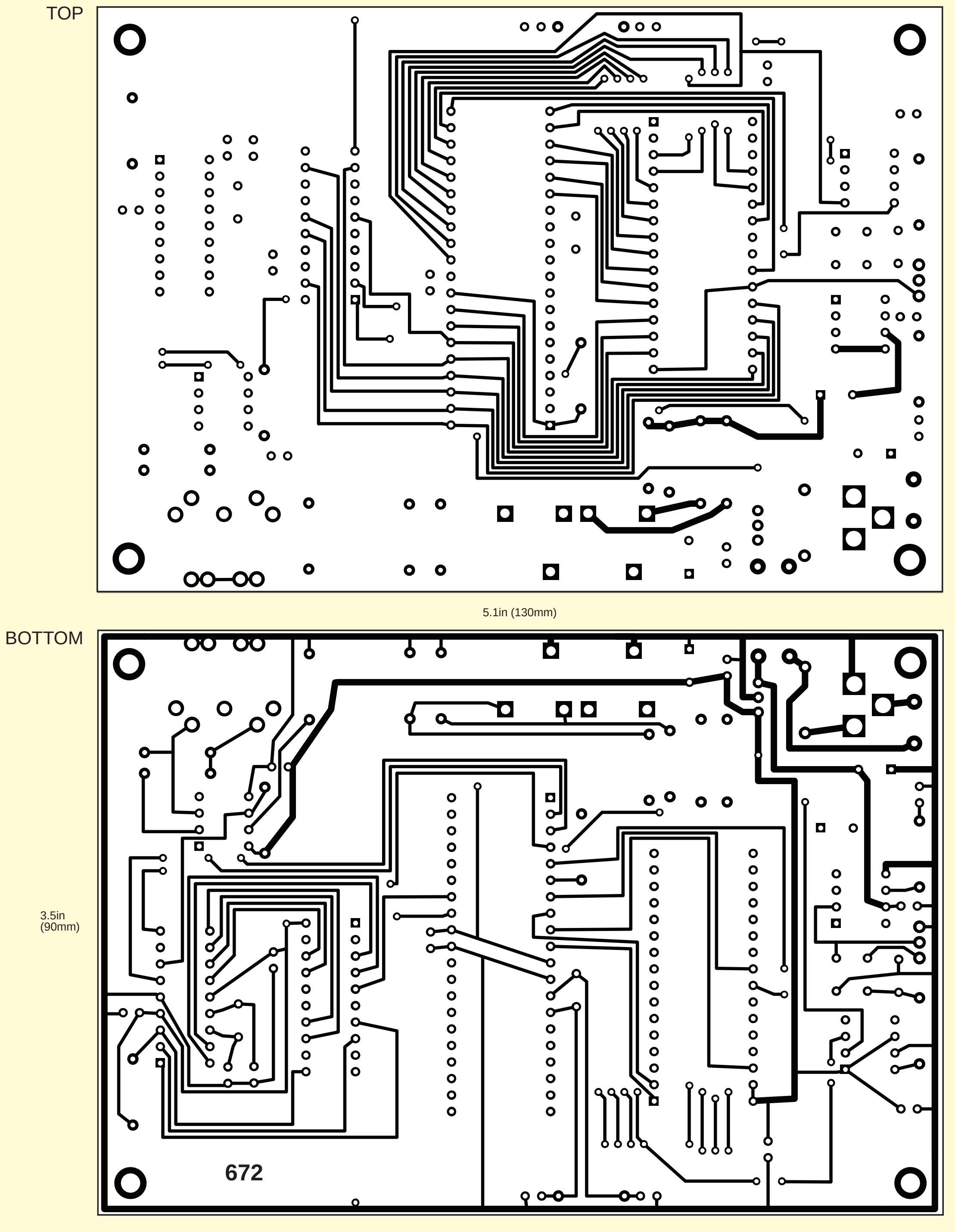


Fig.4: Full-size copper foil masters for the top and underside of the printed circuit board.

To help overcome this problem, a second set of samples for some of the instruments is stored on the EEPROM for notes above *F5*. These samples have been filtered in a wave editor, with a low-pass frequency of between 3675Hz (1/3 of the sample rate) and 5512Hz (1/2 the sample rate). Admittedly, this is a compromise, but the results are still quite acceptable.

Construction

All the components, except for the on/off switch, LED indicator and resistor, Volume control and battery pack (if you use one) are mounted on a double-sided PCB (printed circuit board). This will make construction fairly straightforward, and a wide range of suitable enclosures can also be used.

The component layout and full-size copper foil masters are shown in Figs 3 and 4. This board is available from the *EPE PCB Service*, code 672

The input and output sockets are all at one edge of the board, making it suitable to align with the rear of the case. If you wish to mount sockets elsewhere, or use different types of socket, it is very simple to 'hard-wire' these components

Wiring to the front panel mounted components. Note resistor R14 is wired directly between the power On LED and the On/Off switch

to the board. Just remember to keep the wires as short as possible.

Provision has been made to use battery power (six AA batteries), or an external 9V DC adaptor, or both. The switched contacts in the DC power socket (SK2) are used to disable the battery when an adaptor is used. Only an adaptor was used in the prototype.

Start construction by installing and soldering in position the IC sockets and the input and output sockets. It's always a good idea to use IC sockets, as the board can be tested with power on before inserting any expensive ICs. Next, install the resistors, capacitors (ensure correct polarity of electrolytic capacitors), diodes and crystals in that order.

Drill all the necessary holes in the case after building the circuit board, so that the holes can be aligned properly.

Finally, with reference to Fig.3, solder the volume control, on/off switch, LED, resistor and battery pack (if you are using one) to the board with suitable insulated wire.

Testing

Before you start testing, inspect the board very carefully, preferably with a good magnifying glass, to ensure there are no solder splashes across components and copper tracks and no 'dry' solder joints.

When you are confident that everything looks all right, you can apply power to the board and check for between +9V and +12V at the input of voltage regulator IC8 (the positive terminal of C1) and +5V at the output of IC8 (the positive terminal of C3). If these voltages are not present or are way off, switch off immediately and start re-checking.

Carefully insert all the ICs and apply power to the board. If possible, monitor the current being supplied to the board. If all is working correctly, this should be about 50mA with no output from the audio amplifier.

Finally, connect a MIDI device to the MIDI input socket of the Wave Sound Generator, such as a keyboard with a MIDI out facility, using a suitable MIDI cable. Make sure it is a *proper* MIDI cable, because 5-pin DIN cables are wired differently for various applications. Low impedance headphones can be connected to the headphone output socket (JK1), or alternatively you can connect the line output (JK2) to an audio amplifier's line input with a suitable cable.

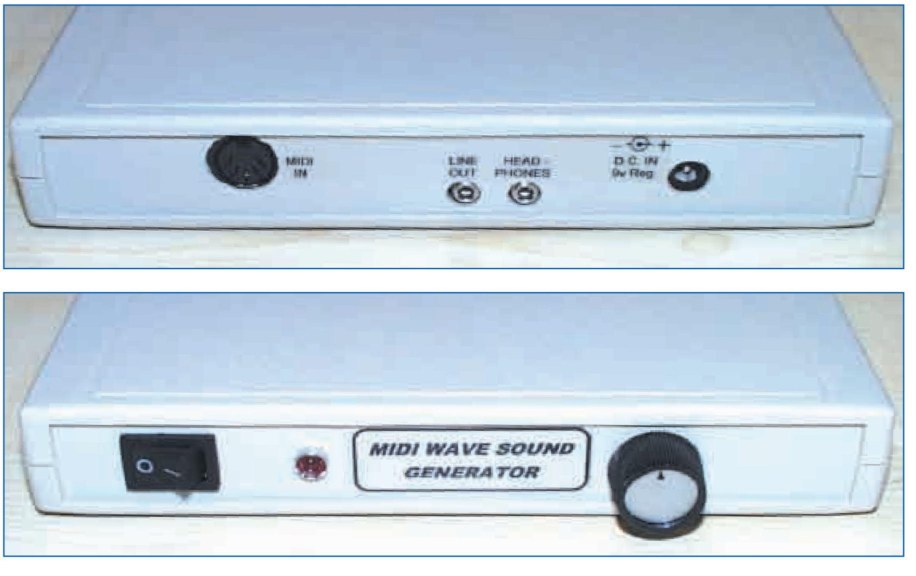
On power up, the MIDI keyboard should default to MIDI Channel 1. You may have to consult the keyboard instruction manual to make sure of this. Now play a few notes on the keyboard and these should be reproduced by the MIDI Wave Sound Generator on its default instrument, which is acoustic piano.

Selecting different instruments on the keyboard will select the correct instrument on the Wave Sound Generator. The MIDI keyboard will normally have at least 128 instrument selections, whereas the MIDI Wave Sound Generator has only 18, so the nearest instrument sound is selected by a table in IC2, the MIDI decoder.

Most MIDI devices should work on the Wave Sound Generator, such as the MIDI output of a PC, MIDI controller or keyboard. Home grown PIC MIDI controllers will also work, providing you keep within the design parameters of the accepted MIDI messages outlined earlier.

Conclusion

The sounds produced by the MIDI Wave Sound Generator could never be classed as hi-fi, but the overall quality is quite acceptable and there is huge scope for experimentation with controllers and other music projects. With enough room on the 512kB EEPROM for another 20 or 30 instrument samples you could start adding your own instrument sounds, for example drum samples. ***EPE***



Front and rear views of the completed PIC MIDI Wave Sound Generator

PIRATE PARTS

Silicon piracy and counterfeit components are a major source of concern to the electronics industry. Should home constructors be worried too? Mark Nelson reports.

Substandard semiconductors are nothing new. If your electronic construction activities reach back to the 1970s you'll doubtless remember those bargain packs of slightly out-of-spec transistors (and TTL logic chips with one gate faulty) that made our hobby more affordable.

Although not good enough to carry the manufacturer's name, these anonymous or relabelled offerings were perfectly adequate for our purposes. So long as you knew they were slightly substandard, you could make allowances.

Back to the present

There's the rub. With cheapo pre-pak transistors you knew what you were buying and the price you paid reflected this. These days you could pay full price for memory chips that might not actually match the speed printed on them. Or you might spend many hours debugging a newly constructed project without realising that the quad comparator chip was defective.

Counterfeit components are obviously a cause of concern for instrumentation and computer manufacturers. They are also a source of upset for audiophile equipment makers, who don't want failing power transistors in their equipment blowing up customers' seriously expensive loudspeakers in the process. Nor do the audiophiles themselves!

This is why Rod Elliott of Elliott Sound Products devotes a whole page of his website to the problem (**http://sound.westhost.com /counterfeit.htm**). As a service to the community at large, he provides an index of counterfeits he and his contributors have discovered, complete with photos of some of them. Dodgy power transistors are rife in the industry, he declares, although any high-priced component is a target for the counterfeiters.

Who loses out?

Everyone's a loser with counterfeit components. The makers of the legitimate product suffer what is these days called 'reputational damage', while end users end up with a substandard product. Component distributors and equipment manufacturers also suffer. As Rod Elliott states, "Counterfeit transistors cost far more than their monetary value; the loss of confidence, wasted time and collateral damage are far worse."

But is this fraud really racketeering or just petty crime? According to Henry Parker, of industry body Intellect, there's no doubt at all. In the USA alone, authorities have already intercepted $70 million worth of suspect semiconductors, he says, while European equipment makers are facing an increasing tide of cleverly disguised counterfeits, often from China and Eastern Europe.

Quoted in trade newspaper *Electronics Weekly*, Adam Fletcher, chairman of UK trade body, the Association of Franchised Distributors of Electronic Components, says that the increasing volume of counterfeit components is a serious problem. "There is real concern in the supply network about the increasing prevalence of counterfeit components within the supply chain," he declares.

Another industry expert, Lloyd Francis, aerospace and defence manager at Alter Technology Group UK, states that out of a batch of 400 devices tested recently by his firm, only five per cent were genuine parts, despite all being branded as being manufactured by a big name supplier. "The key is in recognising that when the source of components changes, so too does the potential risk from counterfeits," he says.

How does it happen?

Counterfeit components look correct, solder to the PCB normally, but then do not function. You might easily assume the component has failed in the assembly process, but it's what's inside the package that counts, sometimes nothing at all.

Tony Gordon of High Wycombe-based SMART Group explains, "Rather than making complicated copies of parts, the simplest thing (for the counterfeiters) is to remark the packaging or the component body. This is simple and quick, while the level of marking is now becoming very sophisticated. Provided the component identification is not checked, all the parts would be placed and soldered to the board before the problem was identified."

Such is the crisis that the SMART Group is holding a workshop session in September, titled *Solving Counterfeit Components*, that will not only illustrate the problems raised by counterfeit components within the electronics industry, but also demonstrate some of the different test methods that can be used to confirm the integrity of the components. Failure analysis techniques are now frequently being used to see if components are what they say they are, rather than finding failure modes.

Beating the bootleggers

Of course, few suppliers offer fake devices deliberately, having bought these components in good faith from sources they believed reliable. Nevertheless, discovering you have been duped after the event can have expensive consequences.

ATG's Lloyd Francis recognises that for equipment manufacturers to test all electronic components entering their system is not a realistic answer to the problem. What he suggests is to confine detecting whether or not you have counterfeit electronic components in the supply chain to when you have suspicions or when you buy components from a new source. ATG offers a comprehensive testing service to equipment manufacturers, and if the results show the parts to be counterfeit, the client avoids a potentially expensive product recall.

Even if the components are found to be genuine after all, the peace of mind that knowledge brings is worth the cost of testing. This, he argues, is "a safe, pragmatic and cost-effective method for detecting counterfeit components."

Vigilance

For hobbyists this is not an option of course, but Rod Elliott has some very practical advice. "Exercise extreme vigilance when purchasing semiconductors, and especially the premium devices," he says. "Be more than careful with devices offered at auctions. Not all will be fakes, but you can almost guarantee that a fair proportion is counterfeit. There is little or no recourse with an on-line seller who can happily disappear after unloading the goods."

Re-marked components or impostors are not the only problem you need to contend with. Inevitably, some manufacturers occasionally produce bad batches of parts, possibly exhibiting a higher than normal proportion of components that fail their spot check tests as a result of something going wrong in the manufacturing process.

Some producers will destroy these bad batches by melting them down or even sending them to landfill (probably not the latter now!). But scrap metal merchants or untrustworthy employees may spot an opportunity to make money by 'recycling' these components back into the grey mar-

Turn a fridge into a wine chiller! Or turn a freezer into a fridge! And save ££££ – that's COOL!

Design by Jim Rowe

That's the all-new

Coolmaster!

Enjoy a glass of wine or two? Got a spare fridge? Why not convert it into a wine cooler to hold your selected tipples at just the right temperature. Or how about converting a surplus chest freezer into a highly efficient refrigerator?

MORE AND MORE PEOPLE are buying a wine cooler for their home. It's a nice idea – keep the wine on display, but at just the right temperature.

An ordinary fridge is too cold for wine storage, but what if you could convert your spare fridge into a wine cooler? It could be much bigger than a typical bar fridge-style wine cooler and probably more efficient into the bargain.

All you need is a precise and adjustable thermostat, which will over-rule the existing fridge thermostat. That's just what the *EPE* CoolMaster does.

In essence, the CoolMaster plugs into the wall power point and the fridge is plugged into it. Then the CoolMaster's temperature sensor is installed in the fridge, with its two- wire lead brought out under the rubber door seal and it then over-rules the inbuilt thermostat.

We've had quite a few requests for an electronic thermostat project, to convert a spare fridge into a wine cooler as simply and safely as possible. So that's how the CoolMaster came to be developed.

An article in the an alternative technology magazine featured a conversion of a chest type freezer into a very efficient fridge. Bingo! We realised that the CoolMaster could do exactly the same job, and with tighter control.

This is a very attractive concept, particularly if you live in a remote cottage operating on solar power.

A chest freezer has much better insulation than a standard fridge and has the benefit that the cold air does not fall out of it as you open the lid. Of course, you do not need to be in a remote location to want to save energy – anyone could employ the same idea to produce a highly efficient fridge at low cost.

So, now there are two applications for the CoolMaster. To convert a fridge into a wine cooler the thermostat needs to maintain the internal temperature at around 9°C to 15°C (48-58°F), while to convert a chest freezer into a fridge it needs to maintain its temperature somewhere between about 4°C and 10°C.

Another advantage of the CoolMaster is that if you ever want to run your fridge or freezer in its original mode, all you do is disconnect it from the CoolMaster – simple!

So that's the story behind this new electronic thermostat project. It's low in cost and easy to build. Virtually all of the parts, apart from the remote temperature sensor, fit on a small PC board, which fits snugly inside a standard UB3-sized plastic utility box.

The lead from the remote sensor plugs into one end of the box, while 230V AC mains power enters at the other end, via a normal mains power cable. The power cable from the fridge or freezer then plugs into a 230V AC outlet on the lid, so the thermostat can control its operation. It's that simple.

It's also quite safe – providing you don't open the box and deliberately touch the mains wiring, of course.

Most of the thermostat circuitry (including the remote sensor) runs from a 12V plugpack and is optically isolated from the 230V AC mains. So, for example, there's no risk of shock from accidental contact with the temperature sensor wiring.

How it works

Fig.1 shows the circuit of the CoolMaster and its operation is quite straightforward. The heart of the circuit is the remote temperature sensor TS1, an LM335Z device specifically designed for temperature sensing.

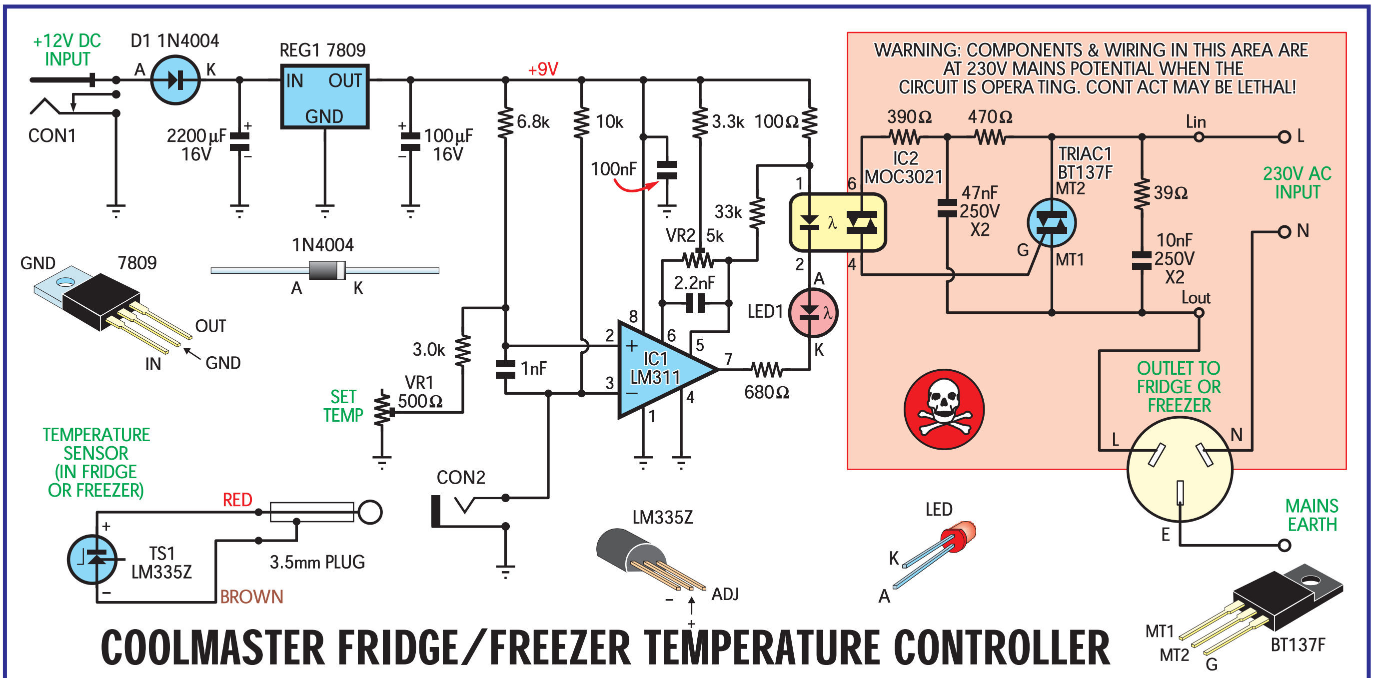


Fig.1: the mains area of the circuit (shown in pink) is isolated from the low-voltage section. But make sure you don't plug the CoolMaster into a power point while the cover is off: it's extremely dangerous!

The LM335Z acts like a special kind of Zener diode, in which its voltage drop is not fixed, but varies linearly and quite accurately with its temperature. In fact, its voltage drop is directly proportional to absolute temperature, having a (theoretical) value of 0V at 0K (–273°C) and rising linearly by 10mV for every Kelvin (or °C) rise in temperature. This is shown in the graph of Fig.2.

So at a temperature of 0°C (273K), the voltage drop of the LM335Z is very close to 2.73V. Similarly, at 16°C (289K), it rises to 2.89V.

It's this change in voltage that we use to precisely control the temperature of our fridge or freezer, by comparing the sensor's voltage with a preset reference voltage.

Sensor TS1 is connected between the inverting input (pin 3) of IC1 (an LM311 comparator) and ground (0V). A 10kΩ resistor also connects from pin 3 to the +9V rail, to provide the sensor with a small bias current. The voltage at pin 3 of the comparator is therefore the voltage across TS1 and is directly proportional to the temperature in the fridge or freezer cabinet.

To provide the comparator with a preset 'set temperature' reference voltage, we connect its non-inverting (+) input (pin 2) to an adjustable voltage divider across the regulated +9V supply rail.

Multiturn trimpot VR1 forms part of the lower leg of the voltage divider, allowing the voltage at pin 2 to be adjusted to any value between about 2.75V and 3.06V.

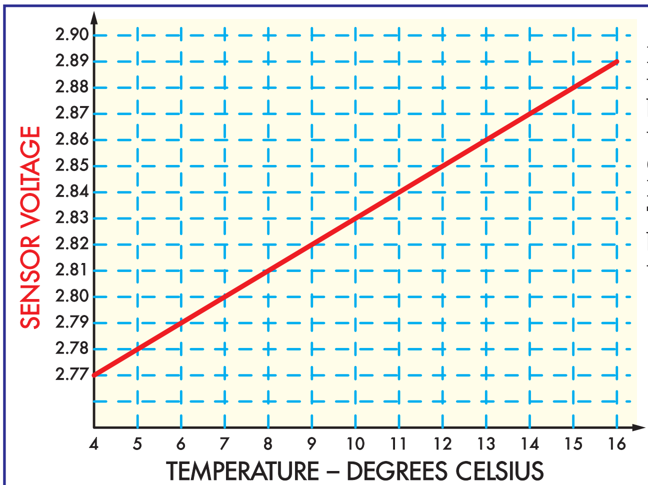


Fig.2: this chart shows the relationship between the temperature and the output voltage of the LM335Z sensor. This information can be used to help set up the CoolMaster.

These voltage limits correspond to a sensor temperature range of 2.5° to 33°C, so it's easy to set the thermostat to maintain the fridge or freezer temperature anywhere in this range.

The maximum temperature of 33°C does seem a little high (hot!) since the normal wine cooler temperature is around 15°C, but since VR1 is a multiturn trimpot which only has to be set once, it's not really a problem.

Whenever the temperature inside the fridge or freezer is lower than the temperature set by VR1, the voltage drop across TS1 will be lower than the preset voltage applied to pin 2 of IC1. As a result, IC1's output (pin 7) will be high (ie, +9V) and both LED1 and the input LED of the MOC3021 optocoupler (IC2) will be off.

However, if the temperature inside the fridge/freezer rises to the set temperature level, the voltage drop across TS1 (at pin 3 of IC1) will match the voltage on pin 2, and the comparator output will swing low (0V) to pull current through LED1 and the optocoupler's LED.

LED1 will turn on and the triac inside the MOC3021 will also be switched on, triggering Triac 1 into conduction as well. This will switch on power to the compressor unit in the fridge/freezer, causing it to cool things down again.

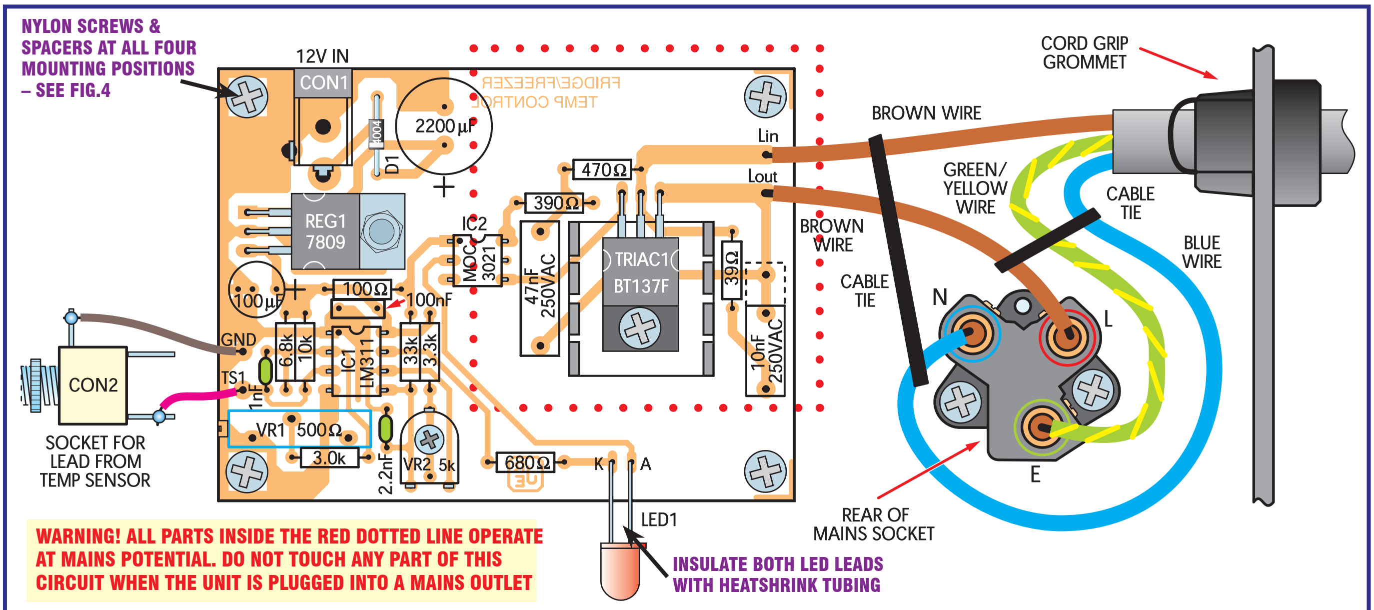


Fig.3: this combined component overlay and wiring diagram should be all you need to put the CoolMaster together. Secure any mains wires together with cable ties – just in case. Remember that components and tracks inside the dotted red line above are at mains potential when operating – never connect power with the case open.

This system runs the compressor only long enough to bring the temperature just below the set level.

Feedback

We prevent the circuit from oscillating or 'hunting' by giving it a small amount of positive feedback, via the 100Ω resistor in series with the optocoupler and LED1, and the 33kΩ resistor connecting back to the balance input at pin 5.

This lowers the voltage at pin 5 when the LED and triac are on and means the input voltage from TS1 must drop down to a level slightly lower than the voltage at pin 2, before the comparator will turn off again.

In other words, we give it a small amount of 'hysteresis'.

Trimpot VR2 is used to adjust the balance of IC1, although with most LM311s it can be left in the centre position.

The 390Ω and 470Ω resistors and the 47nF (class X2) capacitor are used to ensure that Triac 1 is switched cleanly on and off by the triac section inside the optocoupler. On the other hand, the 39Ω resistor and 10nF (class X2) capacitor across Triac 1 are used to protect it from mis-triggering due to 'spikes' which may be generated by the inductive load of the fridge/freezer compressor motor. These parts, along with the triac itself, are at 230V AC mains potential when the thermostat is working.

Therefore, extreme care must be taken when testing or handling the unit. If you do need to open the unit, for whatever reason, you must remove the mains input plug from the wall socket before opening-up.

All of the low voltage part of the circuit operates from 9V DC, generated by regulator REG1 from the 12V DC input via CON1 and protection diode D1.

The 12V input can come from either a 12V battery or a plugpack supply. The current drain is quite low (about 11mA), so you can use the smallest available 12V DC plugpack.

Alternatively, you could use a 9V AC plugpack. This will be rectified by diode D1 and filtered by the 2200µF 16V capacitor.

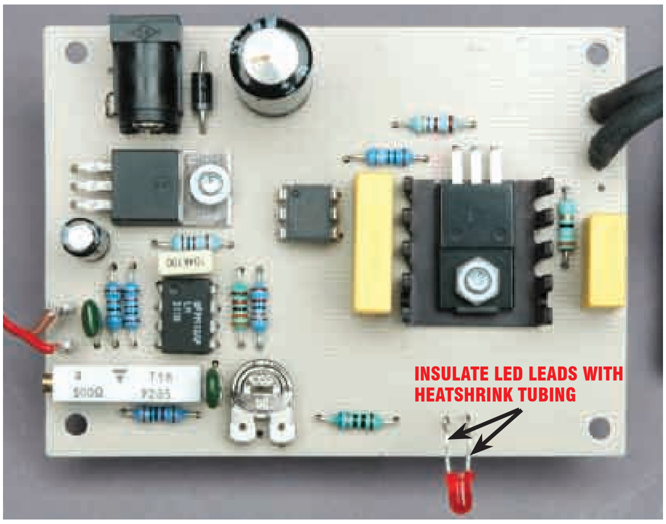
Construction

First, a warning: to ensure safety, you must use a plastic case for this project. In addition, because some of the circuitry operates at mains potential (230V AC), you must mount the PC board on nylon spacers and secure it inside the case (at the top) using nylon screws.

You must also keep the mains wiring short and bind the live, neutral and earth leads together in several places using cable ties, including one tie directly behind the mains socket and another close to the 'Lin' and 'Lout' terminals on the PC board.

That way, if a mains wire comes adrift, it cannot move and contact other parts.

This photo of the assembled PC board shows where everything goes. Be sure to insulate the LED leads using heatshrink sleeving.



This view shows everything assembled in the case, immediately before the lid was screwed on. Note that nylon screws MUST be used to secure the PC board (not metal as used in the prototype).

As a further precaution, you should also insulate both leads of the LED using heatshrink sleeving or some other suitable plastic sleeving and smear the ends with silicone sealant.

All of the components used in the CoolMaster circuit, except for the remote sensor TS1 and its plug and socket, are mounted on a small PC board. This measures just 76 × 57mm and is available from the *EPE PCB Service*, code 675.

As shown in Fig.3, all the low voltage circuitry is at one end of the board and the 'live' circuitry at the other, with the optocoupler IC2 linking them across the isolating gap which separates the two.

Begin wiring up the PC board by fitting the two solder terminal pins. These go near the lower left-hand corner of the board, ready for the wires from CON2 later on.

Next, fit the DC input connector CON1, which goes upper left. It's a good idea to fit this early on, because you may find that the board holes need to be elongated slightly to accept the connector mounting lugs, using a jeweller's needle file.

Now fit the various resistors, making sure you fit each one in its correct position. If in doubt, check their values first with a DMM. Then fit the two trimpots, the smaller non-polarised capacitors and the two 250V AC-rated (class X2) capacitors (which are non-polarised).

The last capacitors to be installed are the two electrolytics; take special care with these because they are polarised. Make sure you follow the diagram carefully for their orientation, or you'll strike trouble later.

Take the same care with the semiconductors, starting with diode D1. Follow this with IC1, IC2, REG1 and finally Triac 1. Note that REG1 and the triac are both in TO-220 packages – don't mix them up! They are both mounted horizontally, with their leads bent down 90° some 6mm from their bodies. Both devices are secured to the board using an M3 × 6mm machine screw and nut, passing through the holes provided in their mounting tabs and the board.

In the case of the triac, there's also a 19mm square finned heatsink between the triac tab and the board, to make sure the triac runs cool even during long periods of operation in hot weather. **DO NOT substitute for the triac. You MUST use an *insulated* tab device (otherwise the heatsink will be at mains potential).**

The next step is to fit LED1, which is initially mounted with its leads straight and vertical. **First, cut two 15mm-long lengths of plastic or heatshrink sleeving and fit these to insulate the leads.** That done, fit the LED in position with its longer anode lead passing down through the right-hand hole (marked A on Fig.3) and the shorter cathode lead through the other hole (K). Pass them down as far as they will go so that the LED body is 15mm above the board and solder them to the board pads underneath.

Make sure that the LED leads are completely insulated, with no gaps at either end. Cover the ends with blobs of silicone sealant if necessary.

Finally, bend both leads forward by 90° at a point 10mm above the board, so the LED will be ready to protrude slightly through the hole in the front of the box when it's all assembled later. Your board assembly should now be complete.

Wiring the sensor

Next we need to wire up the LM335Z temperature sensor (TS1) and the steps for this are shown in Fig.6.

Cut a 60mm length from one end of the two-core ribbon cable that you'll be using for the remote sensor lead and bare about 4mm at each end of both wires.

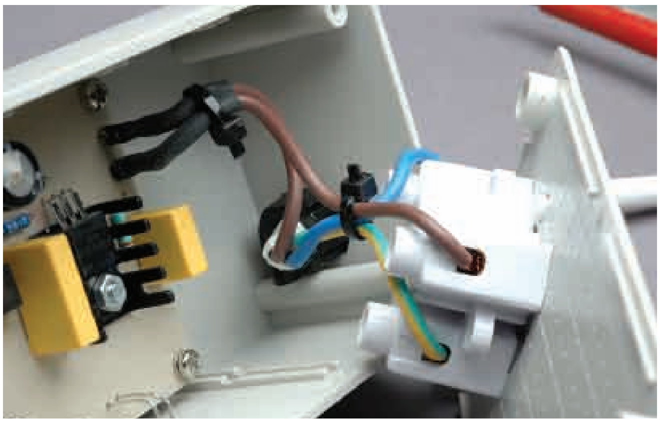
Solder one end of the two wires to the terminal pins on the end of the PC board, just above VR1. Solder the red wire to the lower pin and the brown wire to the upper pin, as shown in Fig.3.

Mains wiring

Next, cut a 75mm length off the free (ie, non-plug) end of the mains cable and remove the outer sleeve so the three insulated wires are exposed.

Discard the blue and green/yellow wires, but bare the ends of the brown wire by about 4mm at one end and 10mm at the other. This will become

Extra close-up view of the mains wiring; note the cable ties around the mains wires, which will secure the 'bitey' bits in this area of the case should they somehow come adrift. Yes, it's unlikely . . . but so was the *Titanic's* iceberg.



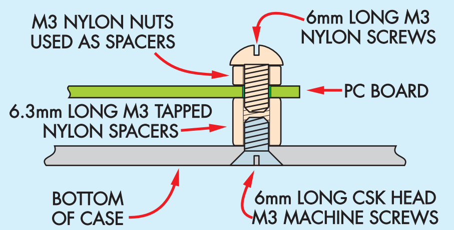


Fig.4: here's how to secure the PC board to the case. You must use nylon spacers and screws where specified, to ensure safety.

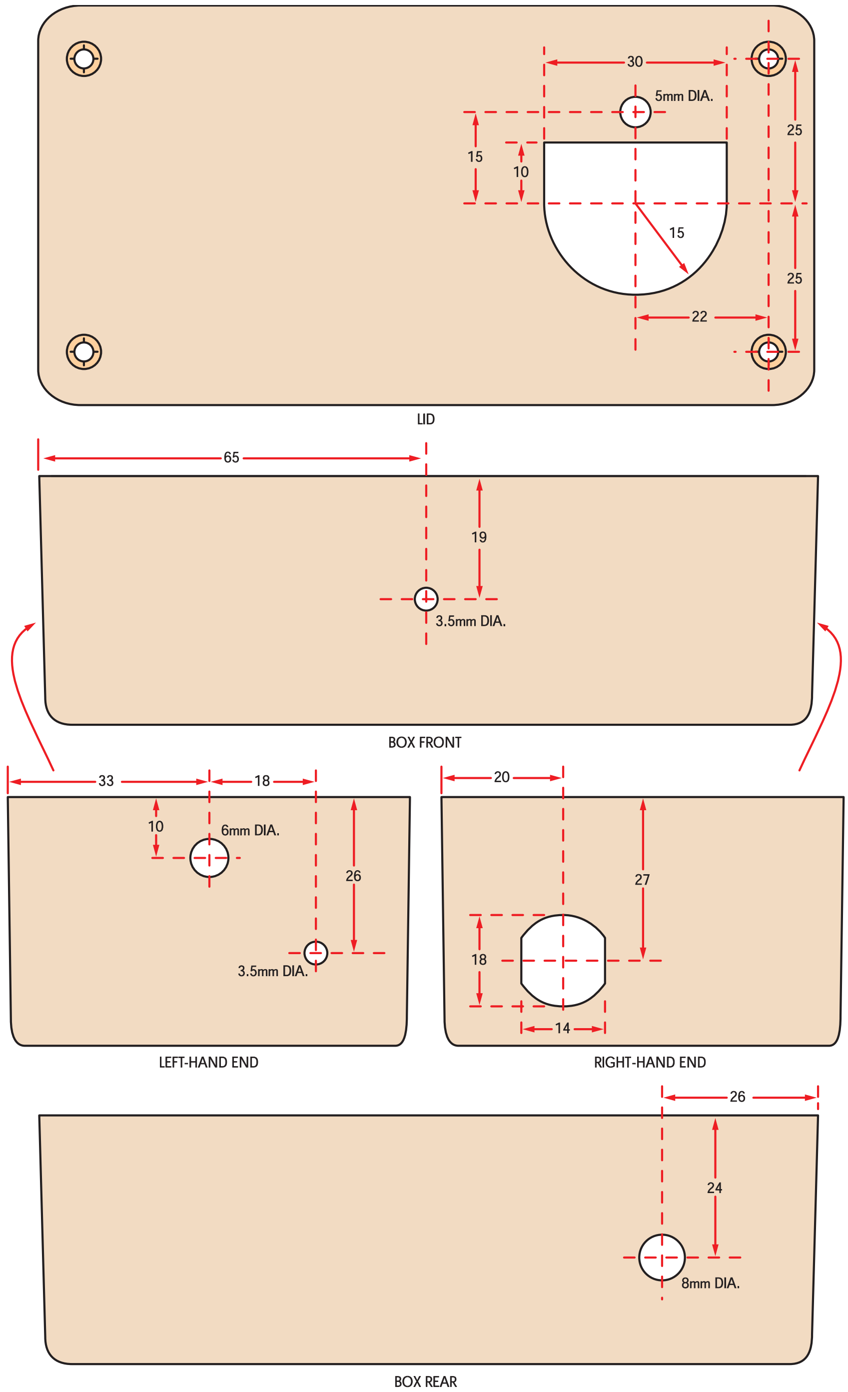


Fig.5: the box drilling details. Note that this is reproduced 80% 'life size'. We suggest you photocopy this at 125% if you want to use it as a template. Also note: The case lid cutout for the mains output socket will, of course, vary according to the socket purchased, ie. the UK three-pin, continental Europe or rest of the world types

the 'Live' wire connecting the output of the PC board to the Live pin of the mains socket (on the lid).

Now carefully push the end bared by only 4mm through the hole in the board labelled 'Lout' and solder it to the copper pad underneath. For the present, just 'tin' the wire at the 10mm bared end.

Now remove another 60mm length of outer sleeving from the free end of the mains cable, to expose the same length of the three insulated wires inside. Take care that you don't nick any of the insulation on the wires inside. Then bare 4mm at the end of the brown wire and 10mm at the ends of the other two wires.

Carefully tin the ends of the longer bared wires, but not the end of the brown wire at this stage.

Next, fit the cable-grip grommet to the outer sleeve of the mains cord, at a point which leaves about 15mm of sleeving before the removed end. Then push the wires at the end of the cord through the large hole in the end of the box (from outside), align the flat sides of the grommet halves with the flats on the hole sides, and finally push both the cord and grommet into the hole until it all clicks into place.

Give the mains cord a firm tug from the outside to ensure it is properly locked in.

Now carefully push the bared end of the cable's brown wire through the remaining 'Lin' hole in the end of the PC board and solder it to the pad underneath.

Next, secure the four M3 × 6.3mm tapped nylon spacers to the bottom of the box using four countersunk-head screws. That done, you can lower the board down into the box until it's sitting on the spacers and fasten it to them using four M3 × 6mm nylon screws with nylon nuts used as spacers – see Fig.4.

You may have to bend the LED leads inwards a little to lower the board into place, but once it is screwed down you should then be able to bend the leads so the LED body protrudes through its matching hole in the side of the box.

Now you can fit the 3.5mm jack socket (CON2) into the 6mm hole in the centre of the left-hand end of the box and tighten its nut to hold it in place. Then you can solder the ends of the two short wires connected to the board's PC terminal pins to its two main connection lugs, as shown in the wiring diagram.

Note that the brown wire goes to the side lug and the red wire to the end lug furthest from it.

Parts List – CoolMaster Fridge/Freezer Controller

1 PC board, code 675, available from the *EPE PCB Service*, size 76 x 57mm
1 plastic jiffy box, UB3 size 130 x 67 x 44mm, grey
1 small U-shaped finned heatsink, 19 x 19 x 9.5mm (6073B type)
1 2.5mm DC power input socket, PC board mounting (CON1)
1 3.5mm mono jack socket, panel mounting type (CON2)
1 3.5mm mono jack plug
1 3-pin mains outlet socket, flush panel mounting type, plus matching mains plug (see text)
1 cable-grip grommet
1 2m 3-core mains cable and 3-pin plug
4 M3 x 6.3mm tapped nylon spacers
4 M3 x 6mm nylon screws
4 M3 nylon nuts
4 M3 x 6mm countersink-head machine screws
2 M3 x 6mm machine screws
4 M3 nuts and star lockwashers
2 PC board pins, 1mm diameter
1 2m length of 2-conductor ribbon cable
2 50mm lengths of 2.5mm heat-shrink sleeving
1 50mm length of 5.0mm heat-shrink sleeving
1 25 x 50mm piece of 3mm aluminium sheet
1 30 x 10mm piece of 1mm aluminium sheet
2 M3 x 9mm countersink-head machine screws

Semiconductors
1 LM311 comparator (IC1)
1 MOC3021 optocoupler (IC2)
1 BT137F 600V/8A triac, insulated tab type (do not substitute)
1 7809 regulator (REG1)
1 3mm red LED (LED1)
1 1N4004 diode rectifier (D1)
1 LM335Z temperature sensor (TS1)

Capacitors
1 2200µF 16V radial elect.
1 100µF 16V radial elect.
1 47nF 275V AC X2 class metallised polypropylene
1 10nF 275V AC X2 class metallised polypropylene
1 100nF metallised polyester
1 2.2nF metallised polyester
1 1nF metallised polyester

Resistors (0.25W 1% metal film)

1 33kΩ	1 10kΩ	1 6.8kΩ
1 3.3kΩ	1 3.0kΩ	1 680Ω
1 470Ω	1 390Ω	1 100Ω
1 39Ω		

1 500Ω multiturn cermet trimpot (VR1)
1 5kΩ mini horizontal trimpot (VR2)

Capacitor Codes

Value	IEC Code	EIA Code
100nF (0.1µF)	100n	104
47nF (0.047µF)	47n	473
10nF (0.01µF)	10n	103
2.2nF	2n2	222
1nF	1n0	102

Mains out

Next, you should fit the mains outlet socket to the box lid. Obviously, the size and shape of the mains socket cutout and fitting arrangement will depend on the type used.

Once the socket is mounted on the lid, bring them close to the box. This will allow you to connect the free ends of the brown wire from the PC board and the blue and green/yellow wires from the mains cable to their respective receptacles on the mains socket, as shown in the wiring diagram (Fig.3).

The brown wire goes to the socket receptacle marked L, the blue wire to that marked N and the green/yellow wire to the one marked E.

You need to unscrew each receptacle's fastening screw a few turns before pushing the wire end inside, and then screw them up tightly again to make sure each wire is held in place securely.

Finally, install the cable ties to secure the live, neutral and earth leads to each other – see photos.

Making the remote sensor

The final stage in building the project is to make up the remote temperature sensor and its lead. You'll find this is again quite easy if you use the step-by-step diagram, Fig.6, as a guide.

As you can see, the first step is to clip off the unwanted third (ADJ) lead of the LM335Z temperature sensor, and then solder the ends of the 2-core ribbon cable wires to the other two leads, after slipping 25mm lengths of 2.5mm diameter heatshrink sleeving over each one.

After the solder cools and you are happy that both joints are good, the sleeves are then moved up until they butt hard against the body of the LM335Z, after which they are heated (a hair dryer on high is usually hot enough) to shrink

Resistor Colour Codes

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❏	1	33kΩ	orange orange orange brown	orange orange black red brown
❏	1	10kΩ	brown black orange brown	brown black black red brown
❏	1	6.8kΩ	blue grey red brown	blue grey black brown brown
❏	1	3.3kΩ	orange orange red brown	orange orange black brown brown
❏	1	3.0kΩ	orange black red brown	orange black black brown brown
❏	1	2.2kΩ	red red red brown	red red black brown brown
❏	1	680Ω	blue grey brown brown	blue grey black black brown
❏	1	470Ω	yellow purple brown brown	yellow purple black black brown
❏	1	390Ω	orange white brown brown	orange white black black brown
❏	1	100Ω	brown black brown brown	brown black black black brown
❏	1	39Ω	orange white black brown	orange white black gold brown

them in place (step 2). Then a 30mm length of 5mm diameter heatshrink sleeving is slipped along the cable and over the other sleeves, and heated in turn to shrink it in place as well (step 3).

Prepare the sensor's heatsink assembly by drilling two 3.5mm holes on the centre line of the 50 × 25mm aluminium plate. They should be 18mm apart and the bottom of each hole should be countersunk to accept countersink-head screws.

Next, make the 30 × 10mm piece of 1mm aluminium strip into a clamp piece, by bending its central 8mm section into a half-round shape to fit over the LM335Z body snugly. After this drill 3.5mm holes in the flat ends of this clamp piece, 18mm apart, again to match the holes in the larger plate.

You should then be able to assemble the probe with the LM335Z clamped to the top of the plate (flat side down) and the screws tightened down using M3 nuts and star lockwashers (step 4).

Complete the sensor assembly by fitting the 3.5mm mono jack plug to the other end of the two-core ribbon cable, connecting the red wire to the 'tip' lug and the brown wire to the 'sleeve' lug (step 5).

Setting it up

There isn't much involved in setting up the thermostat for use. Balance trimpot VR2 can be set to the centre of its range.

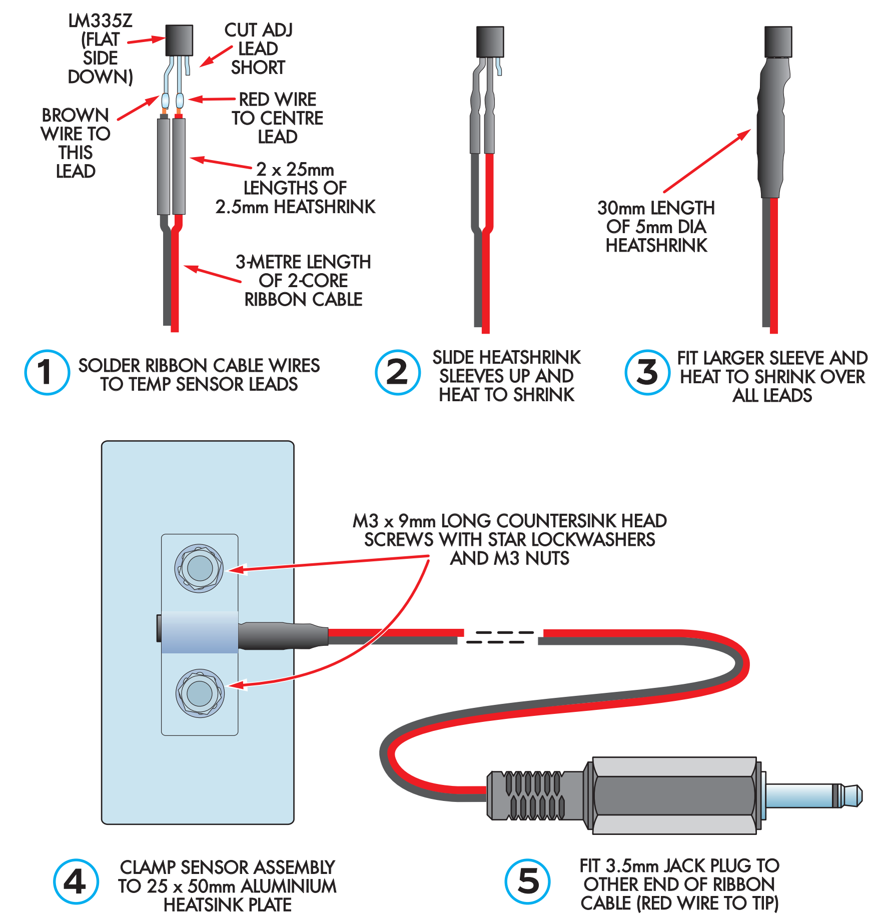
Then, if you know the temperature you want to set the thermostat to maintain, it's a matter of adjusting multiturn trimpot VR1 to produce the corresponding voltage level at pin 2 of IC1.

This can be done by trial and error once the project is finished and working, but if you have a digital multimeter it can also be done before the case is closed up (but *before* the mains cable is connected to the power, of course).

If you want to do this, plug the 12V DC cable from your plugpack into CON2 at the back of the box **but DO NOT plug the thermostat's power cord into a power point.**

Connect the leads of your DMM (set to a low DC voltage range) between pins 2 and 4 of IC1. Read the voltage, which should be somewhere between 2.75V and 3.05V. Now all you have to do is look up the voltage level for the temperature you want from the small graph in this article (Fig.2) and adjust VR1 until the DMM reading changes to this value.

Fig.6: How To Wire The Sensor – Step-By-Step



After this, you can dress the three power outlet wires so that they allow the lid and outlet to be lowered down into the box, until the lid is sitting squarely on the top.

The box assembly is now completed by fitting the four 16mm-long self-tapping screws provided, to hold everything together.

All that remains now is to mount the remote sensor inside the fridge or freezer cabinet, attaching its heatsink plate to the side of the cabinet using two short lengths of 'gaffer' tape. Some double-sided foam pads may also work, but remember that the inside of the cabinet is often moist.

Once the sensor is in position you can run its ribbon cable outside, holding it down with further strips of gaffer tape so it will pass neatly under the rubber door seal when the door is closed.

If you mount the thermostat box on the wall just behind the fridge/freezer, the plug on the end of the ribbon cable can be plugged into CON2 on the end of the box to complete the job.

Now you can unplug the fridge/freezer's power cable from its original power point and plug it into the outlet on the top of the thermostat. Now, when you plug the thermostat's own mains cable into the original wall power socket, the complete system will begin working.

If you want to make sure that the thermostat is holding the fridge/freezer to the temperature you want, this can be done quite easily using a thermometer placed inside the cabinet. Alternatively, you can monitor the sensor voltage across the lugs of the ribbon cable jack plug and verify that the voltage cycles up and down, but is centred on the value for the desired temperature (as shown in the graph).

If you need to adjust the average temperature up or down, this is done quite easily by adjusting trimpot VR1 using a small screwdriver. That's the reason for the small hole in the left-hand end of the box. ***EPE***

PRACTICALLY SPEAKING

Robert Penfold looks at the Techniques of Actually Doing It!

MASTERING component values is one of the first things to tackle when taking up the hobby of electronic project construction. Things are complicated by the fact that some of the basic units of measurement used in electronics are either minute or enormous.

Resistors having values of millions of ohms are in common use, as are 0.000000001 farad capacitors. Matters are further complicated by the wide range of values in common use. The ratio between the highest and lowest values that are generally available is 100 million for resistors and over one thousand million for capacitors.

Low capacity

This could make things very confusing, but the standard metric approach to values makes matters reasonably straightforward. Taking capacitance first, the unit of measurement is the *Farad*, but this is a huge unit by normal electronic standards. A 0.001 farad capacitor could be the largest one that you will ever use, and after almost 50 years in electronic project construction I have never used anything larger than 0.0047 farads.

The values of large capacitors are normally expressed as so many *microfarads*. In the metric system 'micro' is a prefix that means a millionth of, and one microfarad is therefore equal to a millionth of a farad. A 0.00022 farad capacitor would therefore have its value given as 220 microfarads.

The abbreviation for micro is the Greek letter mu (µ), but a lower case letter 'u' is often used instead. On a circuit diagram or in a components list a 33 microfarad capacitor would therefore have its value given in the form of 33µF or 33uF. In practice, this value would often be given as just 33µ or 33u.

Although a microfarad is a mere millionth of a farad, it is nevertheless a substantial amount of capacitance by normal electronic standards. It is much too large for low and middle value capacitors, which usually have their values expressed in *nanofarads* or *picofarads*. A nanofarad is equal to one thousandth of a microfarad. A picofarad is one thousandth of a nanofarad or one millionth of a microfarad. A picofarad is a million millionth of a farad, but capacitors of just a few picofarads are often used in radio equipment. The nano, and pico prefixes are not specific to capacitance, and they are used across the metric measurement system to indicate a thousand-millionth, and a million-millionth of something.

The abbreviations used for nanofarads and picofarads are 'n' and 'p' respectively, and these letters should always be in lower case. A value of 470 picofarads is marked as 470pF or just 470p on a circuit diagram. Similarly, a value of 33 nanofarads is marked as 33nF or 33n.

Things are often taken a stage further in order to conserve space on crowded circuit diagrams. The unit of measurement is also used to indicate the position of the decimal point. For instance, values of 4.7 picofarads and 6.8 nanofarads are often given as 4p7 and 6n8 respectively.

A bit cryptic

Markings on capacitors can appear a bit cryptic at first glance. A 270 picofarad capacitor could simply have its value shown as 270p. In many cases it would be, but particularly with ceramic capacitors, it is quite likely to be marked as 'n27'. The value is being given in nanofarads, but the lack of a leading zero makes the value look a bit confusing at first. 0.27 nanofarads is, of course, the same as 270 picofarads.

Capacitors having values from 100 nanofarads to 820 nanofarads often have a similar problem. Particularly with electrolytic capacitors, a 470n component might be specified in a components list, but this value could be given as 0.47 microfarads in component catalogues, or vice versa.

Another form of cryptic capacitor marking has the value represented by a three digit number. The first two digits of the number are simply the first two digits of the value. The third digit is the number of zeros that have to be added to the basic two-digit value.

As an example, a capacitor marked '473' has 47 as the first two digits of the value, and three zeros must be added to these in order to provide the complete value. This gives a result of 47000, but with the value in picofarads the component is what would normally be regarded as a 47 nanofarad capacitor. This system is essentially the same as the one for resistors, but with numbers being provided for the first two digits and the multiplier.

In the past, it was normal for certain types of capacitor to have their value, voltage, and tolerance ratings marked using a system of colour coding. The method used was firmly based on the system of coding used for resistors. It had a big advantage, which was that minor damage to the markings would still leave the value perfectly readable. The same is not true with components that are labelled with minute lettering. Despite this, capacitor colour coding fell from use many years ago.

Letter imperfect

Capacitors sometimes have additional markings, which are of little real interest, such as batch numbers. Usually, though, the additional markings are something useful, such as maximum voltage and tolerance ratings. The tolerance is simply the maximum amount by which the actual value of the component will differ from its marked value.

Capacitors sometimes have the tolerance indicated by a code letter, and care has to be taken to avoid interpreting a tolerance code letter as part of the value. These are the tolerance ratings for the common code letters:

Code Letter	Tolerance
F	+/– 1%
G	+/– 2%
H	+/– 3%
J	+/– 5%
K	+/– 10%
M	+/– 20%

Examples

The capacitor shown in Fig.1 has rather dotty markings that are not very clear, but its value of 1n5 is given by the first three characters, and the next one is K, which indicates a tolerance rating of ±10 percent. The last three characters presumably indicate that the component's maximum operating potential is 100 volts.

In the example of Fig.2, the two ceramic capacitors are slightly less informative. The capacitor on the left has 22 as the first two digits, with the third character indicating that one zero must be added to these. Its value is therefore 220pF, but no more information is provided.

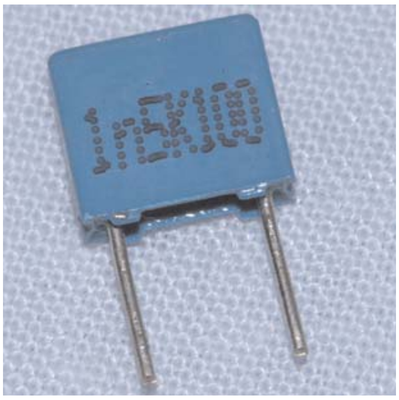


Fig.1. This capacitor has a value of 1n5 (1.5 nanofarads). The additional characters indicate a tolerance rating of ±10 percent and a maximum operating potential of 100V

The component on the right has 68 as the first two digits, with no multiplier present, so its value is just 68pF. The 'J' indicates that it has a tolerance rating of ±5 percent. The orange top probably indicates the temperature coefficient, and is not normally of any importance.

Levels of resistance

The basic unit of measurement for resistance is the *Ohm*. The Greek letter omega (Ω) is used to indicate that a value is in ohms, so a 470Ω resistor has a value of 470 ohms.

Due to the practical difficulties in using anything other than normal alphanumeric characters, the letter 'R' is often used in place of omega. A value of 470 ohms would, therefore, appear on a circuit diagram or in a components list as either 470Ω or 470R, or perhaps even as just 470. It is now standard

practice for the character denoting the unit of measurement to indicate the position of the decimal point as well. A 6.8 ohm resistor would therefore have its value given in the form of 6Ω8 or 6R8.

The basic ohm is fine when dealing with resistors of several hundred ohms or less, but kilohms and megohms are used for higher value components. The prefixes 'kilo' and 'mega' are general ones that are used in the metric system to denote one thousand and one million of something respectively. Thus, a kilometre is a thousand metres, and a kilohm is a thousand ohms. Kilohm is usually abbreviated to kΩ or just k, and the abbreviation for megohm is MΩ or just M. As with basic ohms, the position of the decimal point is often indicated by the letter that indicates the unit of measurement in use. A value of 2.7 kilohms would therefore be shown on a circuit diagram as 2k7, and a value of 1.8 megohms would be marked as 1M8.

Ordinary resistors are available with values from about 1 ohm to 10 million ohms. Components outside this range are produced, but are difficult to obtain, and are not used to a significant degree in electronic projects. Very high value resistors need careful handling to maintain their accuracy, and they are little used in real-world electronics. High-power resistors are only available in a limited range of values, going down to a minimum of about 0.1 ohms. The maximum is typically a few thousand ohms.

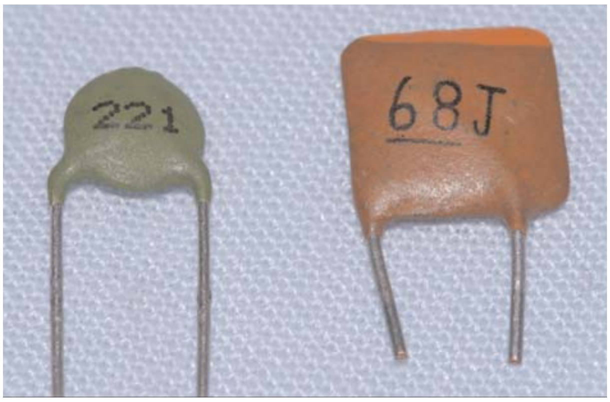


Fig.2. The capacitor on the left has a value of 220 picofarads, but no other information is provided. The component on the right has no multiplier digit, so the value is 68 picofarads. The 'J' indicates a ±5 percent tolerance rating

Colour coding

There are some resistors that have the value written on the body, together with a tolerance rating or code letter, but this method is mainly used with high-power resistors. The normal method of value marking for low-power resistors is a system of colour coding that has four or five coloured bands marked around the body of each component. These indicate the resistance value and tolerance rating. The standard four-band method of coding uses the system shown in Fig.3. Table 1 shows the meaning of each colour, and as will be apparent from this, some colours are not used in all of the bands.

In order to read the codes correctly it is clearly essential to determine the right order. This is often obvious, because the fourth band is usually silver or gold, and neither of these colours are ever used as the first band.

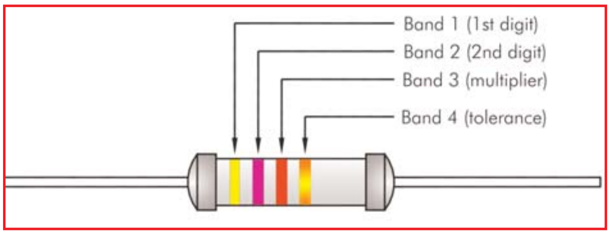


Fig.3. This is the system used to mark the values of most small resistors. The component in this example has a value of 4700 ohms (47 × 100) and a tolerance rating of five percent

The situation is different with close tolerance components which have red or brown as the fourth band, since these colours are also used for band 1. It used to be standard practice for band 4 to be well separated from the other three, but with most modern resistors there seems to be more or less equal spacing of the bands. There is still little likelihood of getting bands 1 and 4 confused and reading the colours in reverse order, since the first band is much nearer to its end of the body, or even right at one end of the body.

As an example of a resistor colour code, suppose that the colours of the four bands are yellow, violet, red, and gold. Bands 1 and 2 provide the first two digits of the value, which in this case are yellow (4) and violet (7). The first two digits of the value are therefore 47. The third band provides the multiplier, and in this case it is red (×100). The final value is therefore 47 × 100, which is 4700 ohms or 4.7kΩ.

The fourth band is gold, indicating that the resistor's value has a tolerance of plus or minus 5%. In other words, the actual resistance of the component is within 5% of 4700 ohms, which works out at somewhere from 4465 ohms to 4935 ohms.

It is worth bearing in mind that it is perfectly acceptable to use a component that has a tighter tolerance than the one specified by the circuit designer. For instance, a one or two percent component can be used instead of a five percent type, but a five percent component should not be used instead of a one or two percent type.

Rather unhelpfully, some resistors have a fifth band. In some cases this only indicates the temperature coefficient of the component, which is usually of no consequence. With these resistors you can just ignore the fifth band and read the value using the first four bands in the normal way.

However, there is another five band version of the resistor colour code, and this type is slightly more awkward to deal with. This form of five-band code uses three bands to provide the first three digits of the value. The other two bands then provide the multiplier and tolerance rating in the usual way. Non-standard values can be accommodated with this type of coding, which is unlikely to be of any practical importance to electronic project builders.

With normal (preferred) values the third band is always black (0). The value can, therefore, be calculated by ignoring the third band, and using the other four bands in the normal fashion. Then multiply this figure by ten in order to give the actual value. For instance, if the four bands provide an answer of 33k, the resistor is actually a 330k component.

If possible, avoid resistors that use this form of five band coding. Ending up with a mixture of these and normal four-band resistors is likely to result in confusion and mistakes.

Table 1: Resistor Colour Code

Colour	Band1/2	Band 3	Band 4
Black	0	x1	-
Brown	1	x10	1%
Red	2	x100	2%
Orange	3	x1000	-
Yellow	4	x10000	-
Green	5	x100000	0.5%
Blue	6	x1000000	0.25%
Violet	7	-	0.1%
Grey	8	-	-
White	9	-	-
Gold	-	0.1	5%
Silver	-	0.01	10%
None	-	-	20%

Choked up

Inductors, or chokes as they are also known, are something of a rarity in electronic projects. The basic unit of inductance is the *Henry*, but one henry is a massive amount of inductance. Most inductors have their value given in microhenries, which are millionths of a henry, but high value inductors have their value specified in millihenries (thousandths of a henry).

Most inductors simply have the value written on the body of the component, sometimes together with other information such as the tolerance or maximum operating current. Small inductors may have the value marked using a system of colour coding that is essentially the same as the type used for resistors. However, the value is in nanohenries rather than ohms. Simply divide by one thousand to give the value in microhenries, or by one million for an answer in millihenries.

Suppose an inductor has the colour code yellow, violet, orange, silver. The first three colours provide a figure of 47000 (47 x 1000), and dividing this by one thousand gives a value of 47 microhenries. Silver as the fourth band indicates that component has a ten percent tolerance rating.

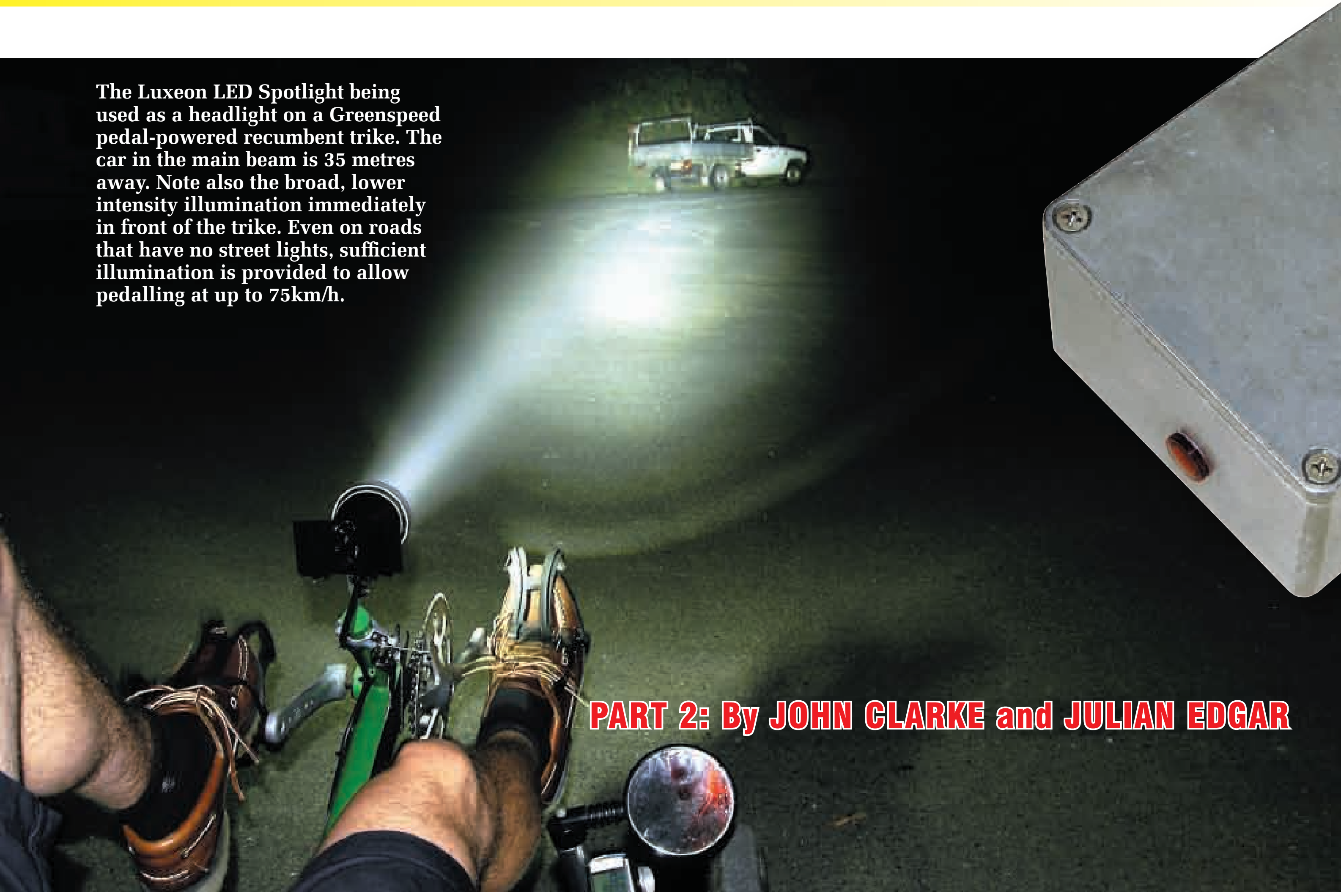
EXCITING CAREER WAITING FOR YOU.

The remote operated vehicle (ROV) industry is one of the fastest growing in all of electronics. Utilising numerous strands of technology and fuelled by the search for oil in ever deeper waters, the world of ROVs is breaking new ground to develop ever more sophisticated vehicles. And as the demand for ROV's increases, the ROV Pilots that operate them are in short supply.

In its simplest form, an ROV is an array of battery powered positional thrusters arranged to facilitate movement in water. These are controlled from the surface via an umbilical which supplies power and thruster commands and also carries images from the ROV's digital camera system. Depending on the role the ROV is undertaking, other equipment such as manipulating arms and cutting, drilling or welding tools can be attached to the ROV. This makes ROVs a very versatile asset to oil exploration companies, especially at depths that are inaccessible to divers.

The skills of piloting an ROV are only second to the ability of the ROV team to ensure that the vehicle is in the water and doing its job. With oil exploration vessels costing hundreds of thousands of pounds a day, time really is money. Planned maintenance, system checks and emergency repairs are all carried out by the pilot team, often in remote locations with the nearest parts shop a lengthy helicopter ride away. Demand for skilled staff is at an all time high and with ever more ROVs being commissioned, this is likely to remain the case. The high demand for ROV pilot/technicians has resulted in pay rates increasing, in some cases quite dramatically. A newly qualified, inexperienced pilot technician straight from an ROV course can expect to earn up to £250 per day. ROV team leaders, who generally have several years experience, can earn four times this amount.

One of the world's most prestigious ROV training schools, The Underwater Centre, is based in the UK and offers a seven week intensive training course that will provide aspiring ROV pilot/technicians with the skills required to embark on a career in the industry. Their seven week long course covers every aspect of ROV flight and maintenance. Further information can be obtained from The Underwater Centre by calling 01397 703786 or by visiting www.theunderwatercentre.co.uk.



The Luxeon LED Spotlight being used as a headlight on a Greenspeed pedal-powered recumbent trike. The car in the main beam is 35 metres away. Note also the broad, lower intensity illumination immediately in front of the trike. Even on roads that have no street lights, sufficient illumination is provided to allow pedalling at up to 75km/h.

PART 2: By JOHN CLARKE and JULIAN EDGAR

Universal High-Energy LED Lighting System

Last month, we introduced our brilliant new Luxeon LED lighting system and described how it works. This month, we look at its construction and describe how to make a very effective Luxeon-powered spotlight.

THE UNIVERSAL High-Energy LED Lighting System is built on a PC board (*EPE* code 673; size 104 x 79mm) and is housed in a diecast aluminium box (115 x 90 x 55mm). An aluminium case was used because it provides sufficient heatsinking for MOSFETs Q1 and Q2 and for the battery pack (this heatsinking is needed at high charge and discharge rates). In addition, the aluminium housing is rugged and weatherproof.

Board assembly

Fig.2 shows the parts layout on the PC board. This board is available from the *EPE PCB Service*, code 673.

Begin construction by carefully checking the PC board for breaks or shorts between the copper tracks. Repair any defects (rare these days), then install PCB solder stakes at all the external wiring points. Follow these with all the low-profile parts, including the wire links, resistors, small capacitors and the diodes.

It might look like a bland box but there's a lot inside! Visible are the cover for the LDR (left) and at right, the on/off pushbutton and the battery status LED. The weatherproof Luxeon output cable can also be seen.

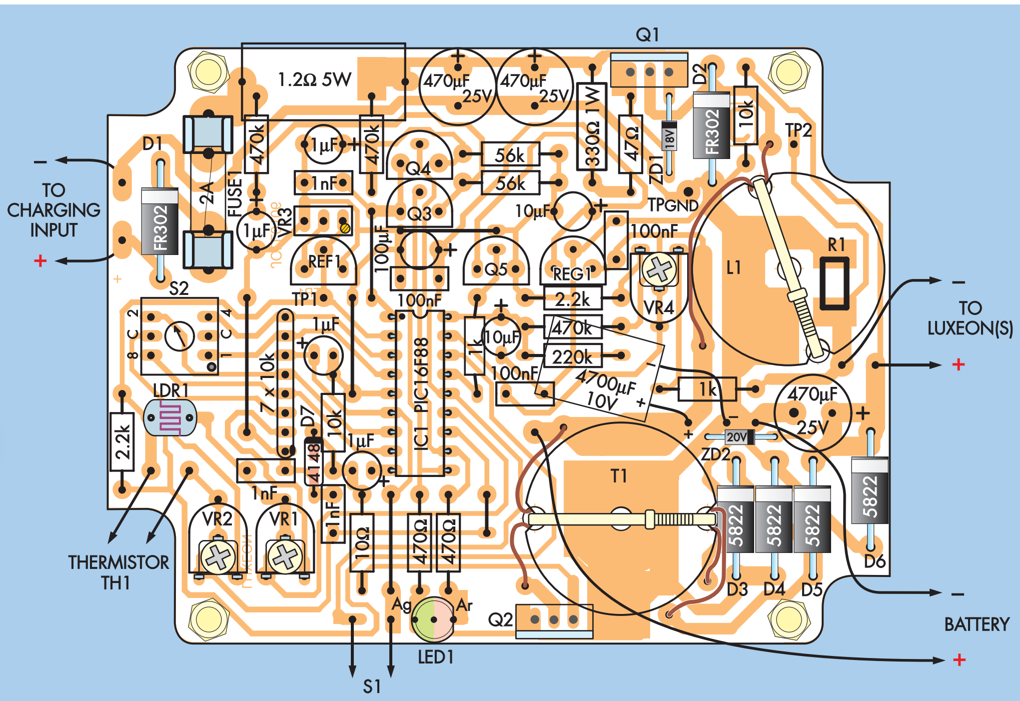


Fig.2: install the parts on the PC board as shown here. Note that R1 is a surface mount resistor and is installed on the copper side of the board. Note also that the 4700µF capacitor is mounted on its side – see photos.

Once these parts are in, you can install the surface-mount resistor (R1) on the *copper* side of the PC board. You will have to refer to Table 4 to determine which of the two provided surface-mount resistors is installed.

Next, install the electrolytic capacitors, voltage regulator REG1 and the transistors, but leave the two MOSFETs Q1 and Q2 out for the time being. Make sure that these parts are all correctly orientated (the same goes for the diodes).

Note that the 4700µF capacitor is not mounted vertically – instead, it is positioned on its side (see photo). Be sure to leave sufficient lead length to allow for this positioning.

Winding the inductors

Inductor L1 and transformer T1 can now be wound. L1 simply consists of 38 turns of 0.63mm enamelled copper wire on an FX2240 pot core and bobbin assembly. By contrast, T1's windings depend on the LEDs being driven (see Table 4). It's also easy to make – just wind on the primary turns, then neatly wind on the secondary turns over the top – see Fig.3. The windings can go in either direction.

When winding T1 and L1, it is strongly recommended that you use a generous smear of silicone sealant under and over each winding layer. Also smear silicone on the top and bottom of the mating surfaces of each core half. **Note that both L1 and T1 require 0.5mm spacers to separate their pot cores (these can be made from 0.5mm plastic sheet). These spacers sit between the central bosses of the pot cores.**

The final step in the construction of these components is to force silicone into the gaps on the outside of the

Table 3: Resistor Colour Codes

❏	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❏	3	470kΩ	yellow violet yellow brown	yellow violet black orange brown
❏	1	220kΩ	red red yellow brown	red red black orange brown
❏	2	56kΩ	green blue orange brown	green blue black red brown
❏	2	10kΩ	brown black orange brown	brown black black red brown
❏	2	2.2kΩ	red red red brown	red red black brown brown
❏	2	1kΩ	brown black red brown	brown black black brown brown
❏	2	470Ω	yellow violet brown brown	yellow violet black black brown
❏	1	330Ω 1W	orange orange brown gold	not applicable
❏	1	47Ω	yellow violet black brown	yellow violet black gold brown
❏	1	10Ω	brown black black brown	brown black black gold brown

Table 4: Transformer Winding Data and LED Current								
Luxeon Option	LED Wiring	Transformer (T1)		R1 2W	TP2 (VR4 adjust)	Individual LED Current	Total LED Current	Test Resistor
		Primary (0.63mm ENCU)	Secondary (0.63mm ENCU)					
1 x 1W		22 Turns	13 Turns	0.5Ω	175mV	350mA	350mA	10Ω 5W
2 x 1W	Series	16 Turns	22 Turns	0.5Ω	175mV	350mA	350mA	22Ω 5W
3 x 1 W	Series	17 Turns	33 Turns	0.5Ω	175mV	350mA	350mA	22Ω 5W and 10Ω 5W in series
4 x 1W	Two lots of series 2 x 1W in parallel	26 Turns	32 Turns	0.2Ω	140mV	350mA	700mA	10Ω 10W
6 x 1W	Three lots of series 2 x 1W in parallel	26 Turns	36 Turns	0.2Ω	210mV	350mA	1.05A	6.8Ω 10W
1 x 3W		22 Turns	17 Turns	0.2Ω	200mV	1A	1A	3.3Ω 5W
2 x 3W	Series	26 Turns	36 Turns	0.2Ω	200mV	1A	1A	6.8Ω 10W
1 x 5W		26 Turns	36 Turns	0.2Ω	140mV	700mA	700mA	10Ω 10W

As shown in this table, the number of turns wound on the transformer, the value of resistor R1 and the adjustment of trimpot VR4 all depend on the number of Luxeon LEDs that are to be driven. In addition, this table shows whether the LEDs are wired in series, parallel or a series/parallel combination. Note: there is no option to use five 1W LEDs.

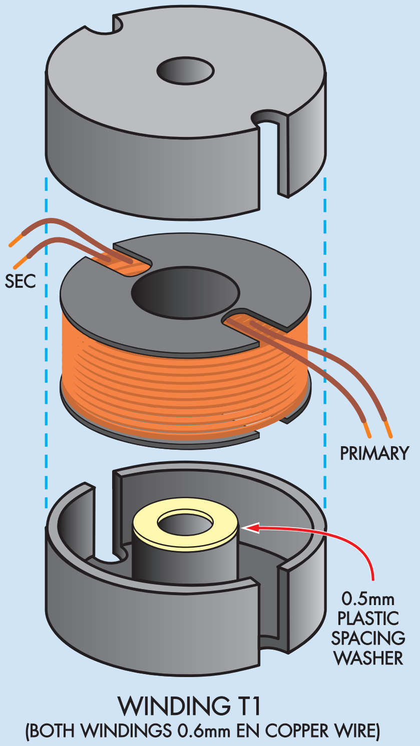


Fig.3: transformer T1 is wound using 0.63mm enamelled copper wire – see Table 5. The windings can be made in either direction. To reduce noise, the windings need to be sealed with silicone, as described in the main text. Note that a 0.5mm spacer is inserted in the middle of the cores for both T1 and inductor L1.

cores. Clean up the edges with a sharp knife when the silicone has set.

Important: if you do not use sufficient silicone, the inductor and transformer will emit buzzes and squeals – so use plenty of it!

Having completed the winding of the inductors, they can be installed on the PC board. Be sure to orientate T1 so that its secondary winding goes to the right, so that the leads connect to the bridge rectifier (D3-D6).

Other parts

Switch S1, the battery charge/discharge LED (LED1) and the LDR can now all go in. In each case, leave sufficient lead length to allow these components to be bent back out of the way when fitting the PC board into the box. The LED must be mounted with its leads bent at right angles, so that it

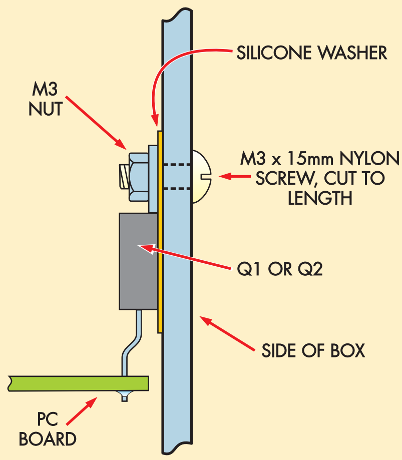


Fig.4: MOSFETs Q1 and Q2 must be insulated from the metal case using insulating washers and nylon screws, as shown here. Note that the nylon screws should be cut to length.

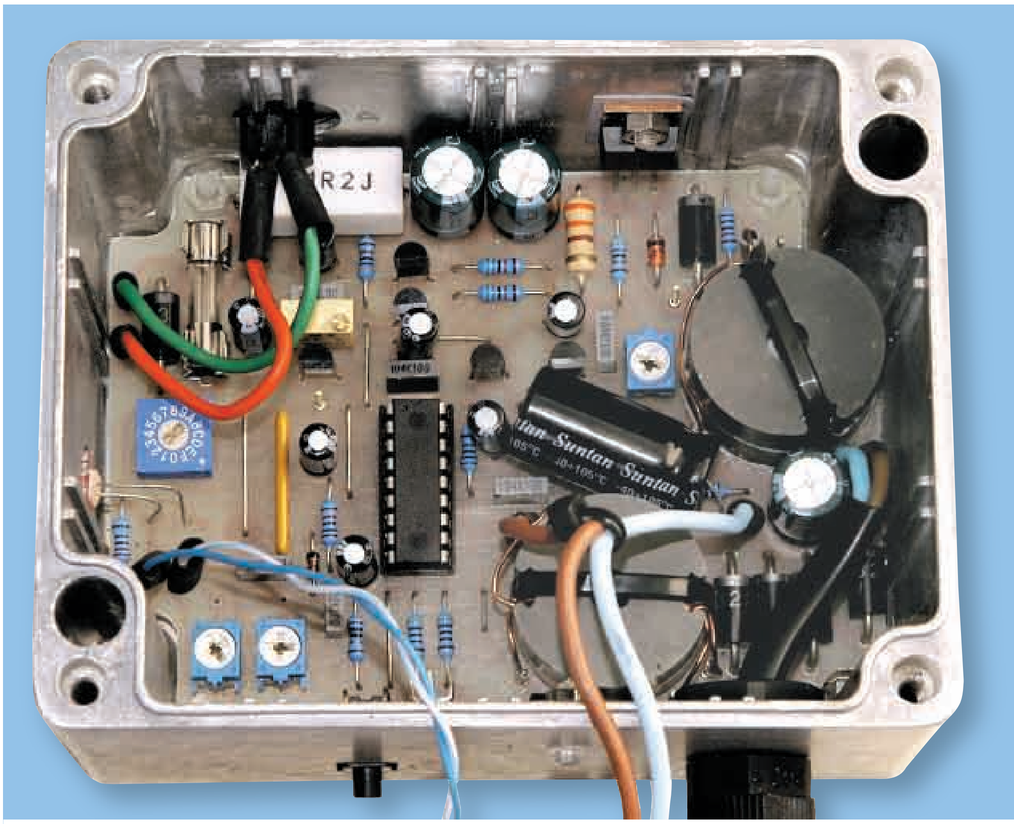
Changing the PWM Frequency

During normal operation, a faint 'squeal' is emitted from the electronic circuitry or more specifically, from the transformer. This can be quietened if a higher (13kHz) PWM frequency is selected, rather than the default 7.8kHz.

The downside is that the dimming functions will not work as precisely. To change the frequency, first select position 14 (E) on the BCD switch (S2). That done, wait for the red LED to come on and then turn off, then select another switch position. The frequency will change from 7.8kHz to 13kHz, which is virtually inaudible in this application.

If you select position E again, the PWM frequency will revert to 7.8kHz.

To provide clearance, the stand-offs within the box must be removed. This can be done by using a large-diameter drill bit followed by a high-speed deburring tool or a grinding stone held in the chuck of an electric drill – wear eye protection!



The electronics are a tight fit in the box, with one capacitor being placed on its side. Do wind the inductors tightly, to minimise audible high-frequency noise.

can later be pushed through a matching hole in the side of the case.

Boxing up

Before the PC board can be fitted into the box, the integral stand-offs need to be removed. This can be achieved using a large diameter drill, followed by a high-speed deburring tool or a grinding stone held in the chuck of an electric drill. Wear safety goggles when performing this job.

Once the standoffs have been removed, position the board inside the case and mark out and drill the four corner mounting holes. These holes should be countersunk, so that the heads of the nylon mounting screws sit flush with the lower surface of the box. That done, temporarily secure the board in position using 4mm-long nylon spacers and 3M x 12mm nylon screws and nuts – see Fig.5.

Note: the four 4mm-long nylon spacers are made by cutting two 9mm spacers in half.

Mounting the MOSFETs

The next step is to determine where the mounting holes go in the case for MOSFETs Q1 and Q2. To do this, first crank their leads slightly, as shown in Fig.4, then slip them into their board mounting holes. Next, push the two MOSFETs down into their holes until they are about 12mm proud of the board and position them so that their metal tabs sit flat against the case.

You can now mark out their tab mounting holes from inside the case. Once that's done, remove the PC board (and the MOSFETs), transfer the hole locations to the outside of the case and drill them to 3mm. These two holes must then be carefully deburred using an oversize drill so that the inside surfaces are smooth and free of any metal swarf which could later puncture one of the insulating washers.

Mounting The PC Board Inside The Case

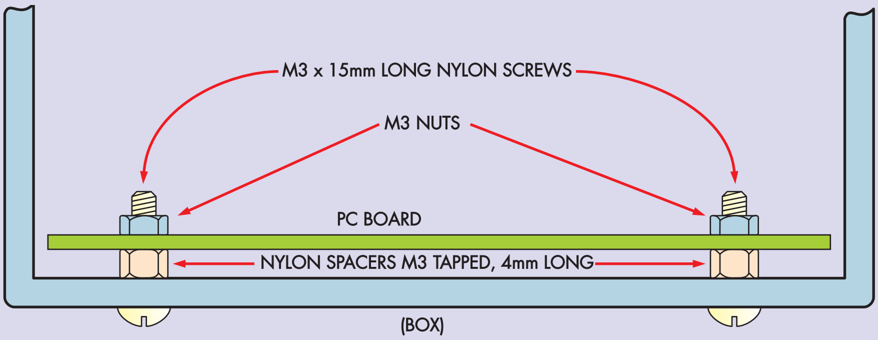


Fig.5: the PC board is mounted inside the case on M3 x 4mm nylon spacers and secured using M3 x 15mm nylon screws and nuts.

Adjusting The Charging Current

In its default condition, the Universal High Energy LED Lighting System is designed to be used with a power source that can recharge the batteries at up to 700mA. Note that because of the temperature rise that occurs primarily in the batteries, this is the maximum recommended continuous charge rate.

However, there are some applications where better results can be gained by altering this charge rate. For example, if you're using a solar cell, you may have a maximum charging current capability of only 300mA available. On the other hand, if you're using a human-powered generator that can develop discontinuous bursts of 1A, you may want to charge at this higher rate. As a result, the charging current can be set anywhere from 100mA to 1A in 50mA steps.

Note that the charging current referred to here is the current delivered to the Universal High Energy LED Lighting System, not the current supplied to the battery.

The current supplied to the batteries is dependent on both the input voltage and the charging voltage. At input voltages between about 8.6V to12.6V, the battery charging current is similar to the input current. Above 12.6V, however, the battery charging current increases with input voltage. For example, at 18V input, the battery is charged at about twice the current that is supplied to the input. This is possible because the charging circuit is a power converter – it converts the high input voltage into a lower voltage to correctly charge the battery and at the same time, increases the battery charging current.

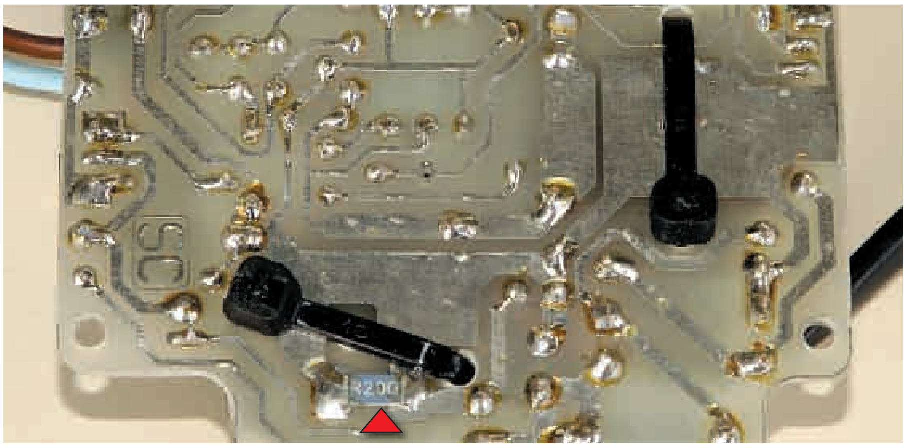
To change the charging current from its default value of 700mA, just follow these two steps:

(1) Set the BCD switch to Mode 15 – marked as 'F' on the switch. The green indicator LED will then flash at a one-second rate, to show the charging current that has been set. Each flash equals 50mA and there is a two-second break between each flash group. For example, at the default 700mA charge rate, the LED will flash 14 times, then there will be a two-second delay, then it will flash 14 times again, and so on.

(2) To alter the charge current, press the pushbutton switch and hold it down, counting the number of flashes. Release the pushbutton when the required current value has been reached. The LED will acknowledge the new setting with a revised flash number.

Note that if the BCD switch is changed while the current reading is being flashed, the LED will continue to flash the code until it finishes its sequence.

Note also that plugpacks are not generally used at their full rating. This means that if you have (say) a 700mA-rated plugpack and you set the charging current to 700mA, you can expect the plugpack to become quite warm.



R1 (arrowed) is a surface-mount resistor that is placed on the copper side of the PC board. Also visible here are the cable ties used to hold transformer T1 and inductor L1 in place.

Adjustments and Test Points

VR1 – sensitivity of the light dependent resistor (LDR1)

VR2 – sensitivity of the thermistor (TH1)

VR3 – reference voltage

VR4 – Luxeon LED current

S1 – operator's pushbutton

S2 – Mode BCD rotary switch

TP1 – test point for setting reference voltage

TP2, TP GND – test points for measuring voltage across R1 to set LED current

The next step is to remount the PC board inside the case, after which the two MOSFETs (Q1 and Q2) are mounted in position. Bolt them to the side of the case using M3 screws, then use a sharp pencil (or a fine-tipped pen) to mark where their leads meet the PC board.

Before removing the board again, you also need to mark out the hole locations for the cable gland, the pushbutton switch, the indicator LED and the charging socket. Similarly, if the LDR is not going to be mounted remotely, a hole also needs to be made for this component (this can go in the lid or in the side of the case).

The accompanying photos show the locations of the various holes. Be sure to position these holes accurately – installing the PC board and its associated hardware in the case requires care, as clearances are very tight. If you don't need such a compact assembly (or the Universal High Energy LED Lighting System is being incorporated into other equipment), then feel free to use a larger box – but don't forget to adequately heatsink Q1 and Q2. Suitable alternative heatsinks are 19 x 19 x 10mm U-shaped designs.

Having marked the hole locations, remove the PC board and the MOSFETs from the case once again. The MOSFETs can now be finally soldered to the PC board – just push them down until the pencil marks on their leads meet the board surface, then carefully solder these leads to their respective pads.

Now drill the holes in the case for the other parts. The square cutout for

switch S1 is best made by drilling a hole that's smaller than the finished size and then filing to the required rounded rectangular shape.

Once that's been done, the PC board can be finally mounted in place (see Fig.5) and the two MOSFETs (Q1 and Q2) secured to the side of the case. Fig.4 shows the mounting details for the MOSFETs. Note that they must be electrically isolated from the metal case. This is achieved by using a silicone washer and by using M3 x 15mm nylon screws and nuts to fasten them in position.

Having secured them, switch your multimeter to a low 'ohms' range and check that the device tabs are indeed correctly isolated from the metal case.

The switch, indicator LED and the LDR can now be pushed through their respective holes and secured in place with silicone sealant.

The cells, main fuseholder and thermistor are glued to the inside of the lid using silicone sealant – see Fig.6. Note the location of the thermistor – it should be placed in the centre of the battery pack.

Make sure that the cells sit hard against the lid and leave plenty of time for the sealant to fully cure before moving the assembly. We used C cells that did not come with solder tags, but since soldering directly to NiMH cells is not recommended, we suggest you use cells with tags. Use 7.5A wire for the batteries, 5A wire for charger leads and twisted pair light-duty hookup wire for the NTC thermistor.

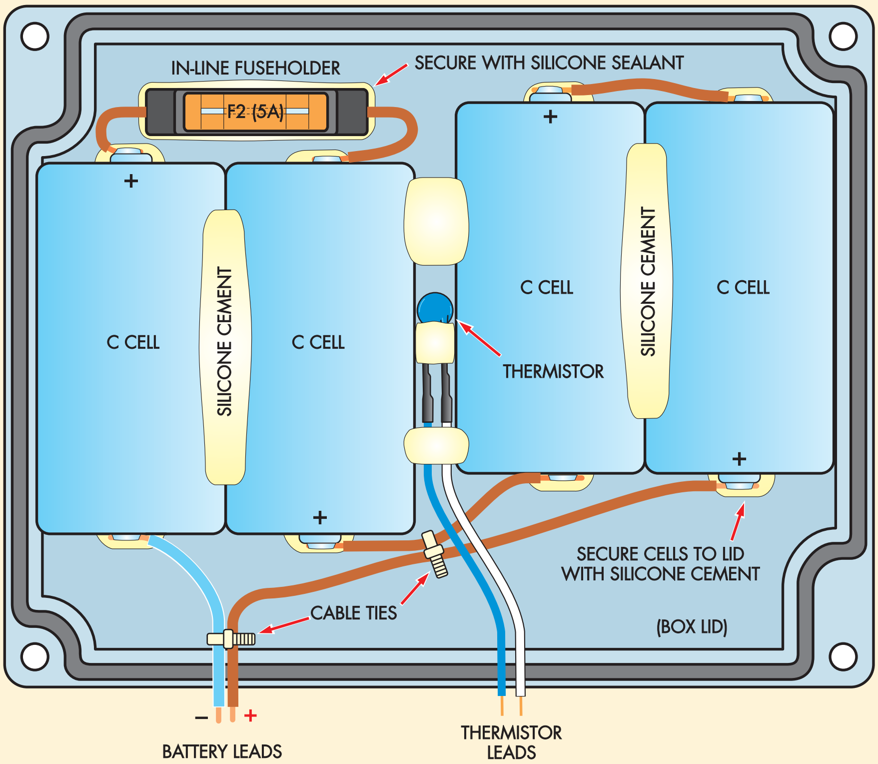


Fig.6: the four 4500mAh cells, the fuseholder and the thermistor are glued to the lid using silicone sealant. They must be wired as shown here.

A few precautions

Before moving on to the setting-up procedure, there are a couple of precautions you need to observe. First, always make sure that the power is off when working on the circuit. This can be done by removing the main battery fuse.

Second, after the circuit has been running, the 4700µF capacitor must be discharged. To do this, press the switch twice in modes 1, 2 or 3 to momentarily light the Luxeon LEDs.

Incidentally, transformer T1 becomes hot when powering a full Luxeon load and at high charge rates, the batteries also become quite warm.

Setting up

Make sure that the battery pack is connected with the correct polarity, then install the fuse. You now need to go through the following set-up procedure:

(1) IC1 power check: Set S1 (the *BCD Mode* switch) to F, then use a multimeter to check that there is battery voltage between pins 5 and 14 of IC1. If there is sufficient charge in the battery pack, this voltage will be 5V.

(2) Adjust the reference voltage (REF1): connect a multimeter between

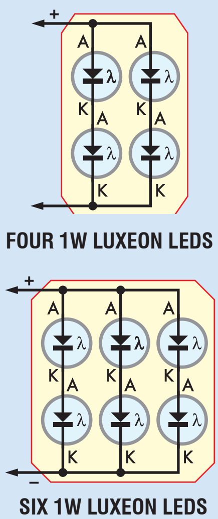


Fig.7: in most cases, wiring the Luxeon LEDs is straightforward. However, when running four 1W or six 1W Luxeons, series/parallel arrangements must be used, as shown here.

Matching The Light From Multiple Luxeons

If the Luxeons are wired with parallel connections, it is best to match the devices so they each have a similar brightness. Devices with exactly the same type number printed on the back are generally the same in terms of voltage drop at the rated current.

If one or more Luxeons in a series/parallel connection is dimmer than the rest, it is not well matched with the others. In that case, reduce the drive current using VR4, so that the brighter LEDs are not over-driven.

This version of the spotlight differs a little from the one described in the text in that aluminium – rather than U-PVC plastic – has been used to form the front rim. The aluminium rim was machined from the base of an old BCF aluminium fire extinguisher. When there's usually plenty of airflow, the heatsink shown on this light is effective with a 5W Luxeon LED. In non-ventilated applications, a larger heatsink should be used.

Making an LED-Powered Spotlight – use it as a bicycle headlight

Bike light

Here's how to build a durable and effective LED-powered spotlight – great for use as a bike headlight or for use as a hand-held long-range lighting system. The light output is simply outstanding – in fact, when you consider its miserly 5W power consumption, it's nothing short of fantastic.

Apart from the electronic control, you only need a handful of extra parts. The accompanying parts list shows what you need.

Building it

OK, let's build it. First, cut a hole about 65mm in diameter in the centre of the plastic plumbing cap. Sand the edges smooth and then use silicone to glue the lens within the cap. This assembly forms the focusing lens.

Next, drill holes in the heatsink to allow small nuts and screws to be used to attach the LED to the heatsink. Drill an additional pair of holes in the heatsink to allow the power supply wiring to the LED to pass through the heatsink. Alternatively, these wires can pass through a hole drilled in a stainless steel drinking cup.

Now use a file to shorten the plastic legs of the collimating lens so that it sits squarely over the LED, legs resting against the heatsink and the centre of the collimator in contact with the LED. Place some heatsink compound under the LED and then attach it to the heatsink using the small screws and nuts. Check that the heads of the screws do not short the power supply connections to the LED (you may want to use nylon nuts and bolts).

Once the LED is in place, glue the collimating lens securely in place. That done, pass the wiring through the heatsink and solder it to the LED, then seal the holes through the heatsink with silicone.

The next step is to cut a 35mm dia. hole in the centre of the bottom of the stainless steel cup. If the spotlight is to be permanently mounted, drill the cup for any brackets that will be needed. Deburr all holes, then position the heatsink on the bottom of the cup so that the LED and collimator lens project through the 35mm hole.

Finally, mark and drill the holes to bolt the heatsink to the cup, sealing this join with silicone.

Testing

Test the operation of the LED with the focusing lens in place. The assembly should throw a very bright spot of light about 600mm wide on a wall three metres away. This beam angle is ideal for a long-range bike headlight, or for a general-purpose spotlight or high-powered torch.

Parts List

1 5W Luxeon LED
1 narrow-beam collimating lens (eg, Jaycar ZD-0420)
1 large finned heatsink to suit the LED – or an ex-PC processor heatsink
1 stainless-steel drinking cup
1 U-PVC plastic plumbing cap that fits over the open end of the cup
1 magnifying glass (glass – not plastic!) the same diameter as the open end of the cup
Assorted small nuts and bolts

Cup note
In most cases, the cup mouth will have a diameter of 75mm, making it easy to source the plastic cap and magnifying glass.

If all is working satisfactorily, use silicone sealant to glue the lens assembly in place.

Performance

The performance of the prototype unit – used as a bike headlight – was outstanding. On a country road lacking any street lights, and tested on a very dark night with no moonlight or starlight, sufficient illumination was provided by the headlight to allow for safe pedalling downhill at over 75km/h. Used as a handheld spotlight, it could easily illuminate trees 50 metres away.

If less power is required, a 3W LED can be used in place of the 5W LED. If the assembly is always going to have airflow over it (eg, if it is being used as a bike headlight), the 3W LED can be bolted to the inside of a single-wall cup and the cup itself used as the heatsink. This saves having to make the large hole in the bottom of the cup and removes the need for a separate, finned heatsink. However, a stationary 3W light should retain the finned external heatsink.

If you want the best, though, use the 5W design described above! If you simply want a compact but nevertheless very effective spotlight beam, the 3W Luxeon, with the Jaycar narrow beam collimator (Cat. ZD-0420) gives excellent results.

Making A Low-Cost 1W Luxeon LED Housing

Here's how to make a durable and good-looking weatherproof housing for a 1W Luxeon LED when it's used with either Jaycar ZD-0420 or ZD-0422 collimators.

You'll need a PVC 25mm Class 18 pipe cap, some black silicone and a few hand tools.

Start by using a file and sandpaper to smooth away any raised writing to be found on the back of the cap (this doesn't do anything for the engineering but a lot for the aesthetics!). That done, drill a hole for the cable entry and also any other holes needed for mounting brackets. If used, the brackets should be attached at this point. And if you intend painting the housing and bracket, do it now.

Next, solder the wires to the LED, feed them through the hole in the housing and position the LED at the bottom. Secure it in place with some silicone, then shorten the legs on the collimator so that it sits over the top of the LED. Carefully apply silicone around the upper part of the collimator, ensuring that you seal the gaps.

You can now slide the collimator into place in the housing, making sure that it engages with the LED. Use a rag to carefully wipe away the surplus silicone, but be sure to fill any gaps around the edge of the LED. Finally, place a little silicone around the cable exit to seal this opening.

Note that because there is no provision for heatsinking, this housing is not suitable for 3W and 5W LEDs.

the negative battery lead and TP1. Adjust VR3 for 2.490V.

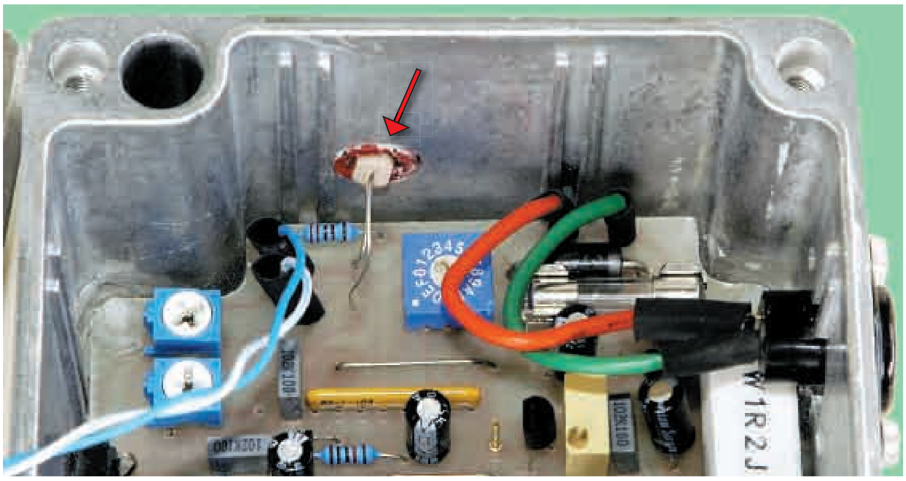
(3) Thermistor calibration: adjust trimpot VR2 so that there's 1.25V across the thermistor terminals at 25°C.

(4) Connect the test resistor: wire a test resistor across the Luxeon LED output (ie, in place of the Luxeon LEDs). Table 4 shows the value to use. Also, use Table 4 to check that both R1 and T1 are correct.

(5) Setting the LED current: set VR4 fully anticlockwise and set S2 to Mode 1. Switch on the system by quickly pressing S1 twice. Measure the voltage between TP GND and TP2.

Set the correct voltage using VR4, according to Table 4. **Note: during this process, the test resistor will get very hot.**

(6) Connecting the LEDs: wire in the Luxeon(s), making sure their polarity is correct and **ensuring the Luxeons are adequately heatsinked!** Again,



The multi-position BCD switch (centre) sets the operating mode of the system. Also visible is the Light Dependent Resistor (arrowed) that's used in some modes to automatically switch on the Luxeon LED as ambient light changes. Depending on requirements, this LDR (arrowed) can either be mounted within the box (and sensing the light through a cut-down neon bezel) or mounted remotely.

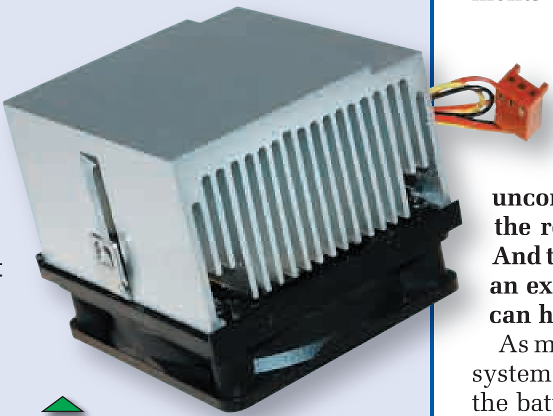
Be Sure To Provide Adequate Heatsinking

Heatsinks must be used with both 3W and 5W Luxeon LEDs. Even the 1W LEDs, which normally don't require additional heatsinking, can do with some additional heatsinking when run continuously at full power in hot conditions.

In all cases, keeping the LED junction temperature low will give greater light output and longer LED life.

The size of the required heatsink depends on:

- The nominal power of the LED
- If it is run at maximum current
- If it is on continuously or is flashed (and if flashed, the duty cycle)
- Ambient temperature
- Ventilation
- Thermal resistance of the heatsink.



ABOVE: a processor heatsink salvaged from an old PC is ideal for cooling 3W and 5W Luxeon LEDs. Remove the old heat transfer pad in the centre using solvent, before attaching the LED.

If there is plenty of space available, it pays to simply run the best heatsinking possible. In all cases, care must be taken to ensure that the aluminium face of the PC board used for the LED is thermally connected to the heatsink. The heatsink must be absolutely flat (no burrs from drilled holes), and a smear of heatsink compound should be placed between the LED's PC board and the heatsink. In addition, the LED should be held in place securely with nuts and bolts.

Ex-PC processor heatsinks are excellent for Luxeon LEDs, with older 486-sized heatsinks suiting 3W LEDs and larger heatsinks from later model PCs suiting the 5W LEDs. If ventilation is poor, the fan that's often found attached to these heatsinks should be retained.

If the LED drive voltage is nominally 6.8V (as it is when running a single 5W LED or two series 3W LEDs), the fan can be wired directly across the Luxeon output. It will rotate more slowly than if fed from 12V, but will still spin fast enough to greatly improve heatsink performance.

Note that the current should be increased to take into account the fan draw. The required increase in the setting of VR4 can be calculated by multiplying the fan current in amps at 6.8V by the value of R1, which in these LED applications is 0.2Ω. Typically, it's about a 15mV increase.

In short, be generous with the heatsinking and if the heatsink gets hot during operation, consider using a larger unit. Alternatively, consider adding a fan if you haven't already done so.

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Where To Buy Programmed PICs

For those capable of doing their own programming, the software (luxeon.hex) for the PIC16F88-E/P microcontroller used in this project is available for free download via the EPE Downloads site, access via **www.epemag.co.uk**

Alternatively, you can purchase a programmed microcontroller from Magenta Electronics (www.magenta2000.co.uk), see their advert.

Note: it's unlikely that a complete kit of parts will be offered for this project. However, you should have little difficulty buying the parts separately from parts retailers. The PC board can be purchased from the *EPE PCB Service*, code 673, see page 78.

measure the voltage between TP GND and TP2 and make the final adjustments using VR4 and Table 4.

The reason that the test resistor is initially used in place of the Luxeon LED is for safety. If you have made a major mistake that results in uncontrolled current at the output, the resistor will simply get hotter. And that's much better than blowing an expensive LED – something that can happen in the blink of an eye.

As mentioned last month, when the system is switched off, it's normal for the battery monitor LED to flash momentarily every second or so.

Wiring the supply plug

If you're using a plugpack and/or car cigarette lighter plug to charge the Universal High Energy LED Lighting System, you'll need to wire a 2-pin DIN plug to the power source.

In the case of a plugpack, cut off the original DC plug and separate and bare the ends of the cable. Slip the DIN plug cover over the cable, then use a multimeter to determine the polarity of the plugpack output. Solder the positive lead to the smaller of the two DIN plug pins and the negative to the larger pin.

Make sure that the connections cannot touch one another – you may want to use some electrical tape or heatshrink around the soldered connections.

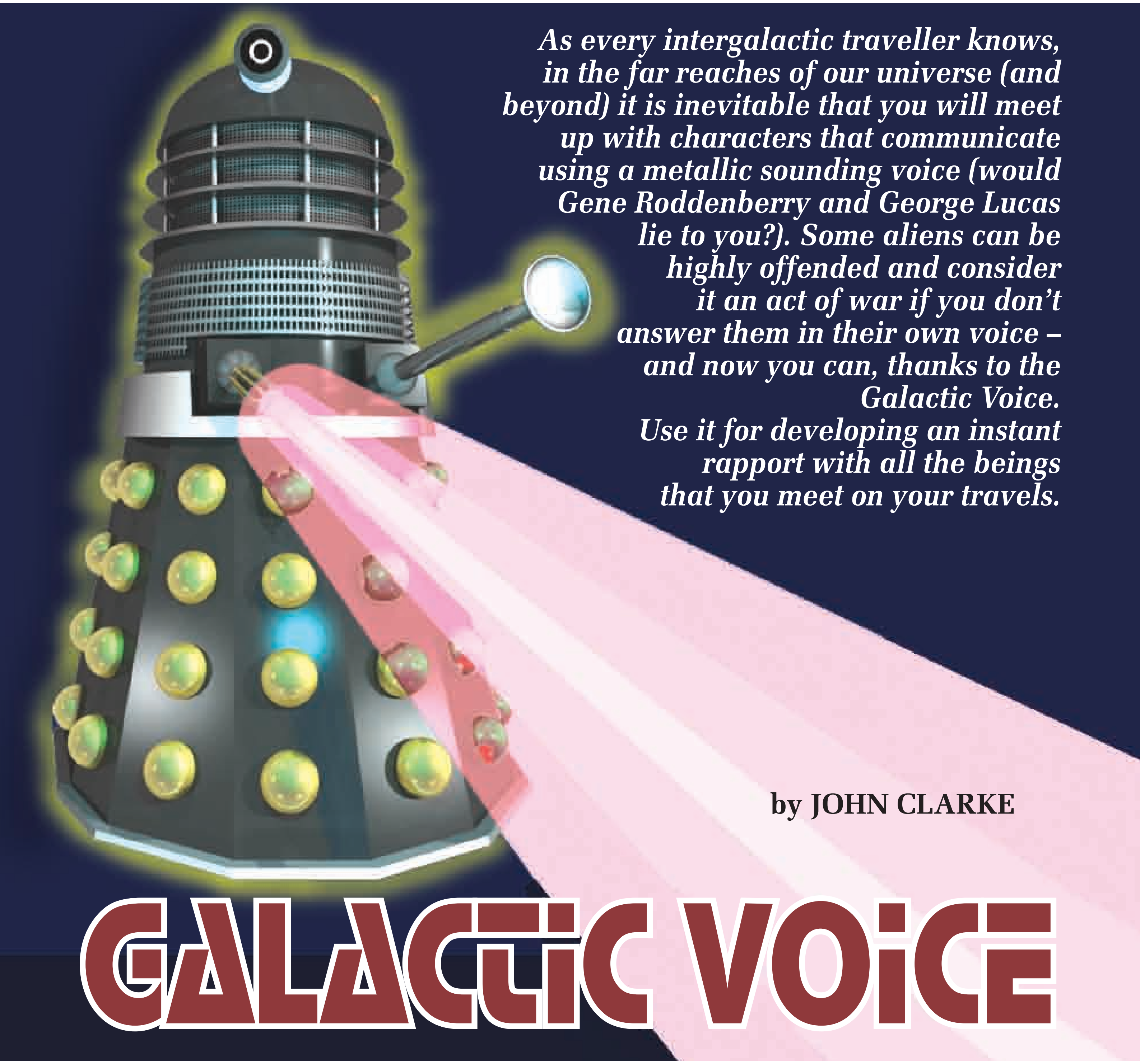
Finally, slip the DIN plug cover back over the plug and use a multimeter to confirm that the voltage polarity is correct.

The procedure is similar for a cigarette lighter plug. In this case, you have to connect a 5A (minimum) figure-8 cable between the lighter plug and the DIN plug (don't forget to first slip the cigarette lighter plug and DIN plug covers over the cable).

Connect the smallest DIN plug pin to the tip of the cigarette lighter plug. The larger DIN plug pin then goes to the side (chassis) connection of the cigarette lighter plug.

Conclusion

Despite its unassuming appearance, the Universal High Energy LED Lighting System required a major investment in time and effort. The result is a LED lighting system that's unmatched in flexibility and application. *EPE*



As every intergalactic traveller knows, in the far reaches of our universe (and beyond) it is inevitable that you will meet up with characters that communicate using a metallic sounding voice (would Gene Roddenberry and George Lucas lie to you?). Some aliens can be highly offended and consider it an act of war if you don't answer them in their own voice – and now you can, thanks to the Galactic Voice.
Use it for developing an instant rapport with all the beings that you meet on your travels.

by JOHN CLARKE

GALACTIC VOICE

WE'VE ALL SEEN and heard those sci-fi TV programmes and films which include characters – either real 'living' beings or fully robotic droids – that speak with electronic-sounding voices.

The living beings are often heavily modified with mechanical and electronic prosthetic devices. The modifications extend to voice-changing headpieces designed to cause menacing expressions.

The voice changing tends to bring out the worst evil features from the characters. Some examples of characters from the galaxy with metallically challenged voices – and bad attitudes! – include the Droids from *Star Wars*, the Cylons from *Battle Star Galactica* and of course the Daleks from *Dr Who*.

Who can resist holding their arms out and coldly ordering: "exterminate, exterminate, we are the Daleks" especially when armed with a metallic-sounding voice?

Each of these characters has their own distinctive voice signature and the Galactic Voice project includes controls to match the required character.

Imitating the voices is as simple as switching on the Galactic Voice and speaking in a normal voice into an inbuilt microphone. The electronics and the loudspeaker do the rest for you, converting your normal, totally boring voice into a metallically accented diabolical one.

There is an 'Effect' control which changes the metallic effect by changing the pitch of the metallic sound

Just add your voice and you too can sound like a Klingon, Dalek, Droid or Cylon... you name it!

from a high pitch through to a low one.

There is also a 'depth' control, which adjusts the amount that the metallic sound is impressed upon your voice, from a relatively normal voice through to a fully metallic voice.

A volume control sets up just how much sound you can deliver to your fearful audience. The maximum overall volume is similar to that produced by your own voice when speaking normally. Too much volume will cause feedback between the microphone and loudspeaker and produce a loud squeal.

How it looks

The Galactic Voice unit comprises a 120mm-long, flared plastic tube with a loudspeaker mounted inside the flared end. The controls are located at the opposite end of the tube. This end is held close to the mouth so that you can speak directly into the microphone.

A power switch is used to switch the Galactic Voice on or off and an LED indicates when power is on.

How it works

The block diagram for the Galactic Voice is shown in Fig.1. The signals from the microphone are amplified by IC1 and sent to a mixer (IC3). This combines the amplified signal with a square wave carrier signal produced by variable frequency oscillator IC2.

The frequency of oscillation is set by the Effect control, while the Depth control sets the amount of signal that is applied to the mixer.

Output from the mixer is the carrier signal produced by the oscillator, but with the level of this signal following the shape of the amplified microphone waveform.

Not surprisingly, this significantly changes the way the signal sounds – the sound produced is similar to the metallic sounding voices we know so well.

The resulting metallic voice sound is passed to the power amplifier (IC4) via the Volume control (VR3).

The waveforms overleaf show the results of the modulation, where the oscillator signal is mixed with the amplified audio signal from the microphone.

The waveform at the top is the amplified signal from the microphone, while the lower waveform is the signal after the mixing. The signal shown is taken from the power amplifier output. You can see that this signal is the oscillator waveform modulated in level according to the microphone signal.

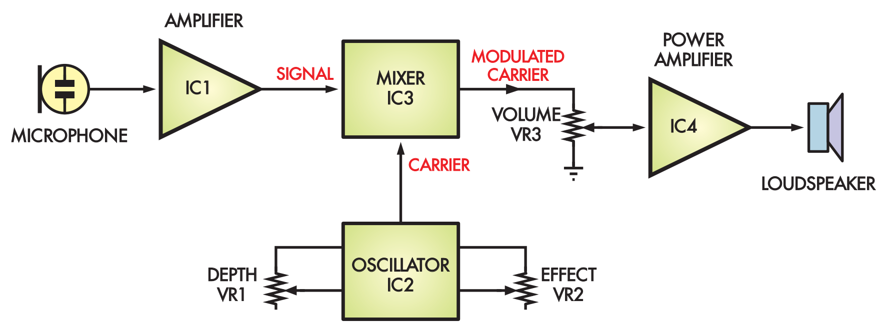


Fig.1: the block diagram of the Galactic Voice box. Compare the functional blocks with the circuit diagram overleaf.

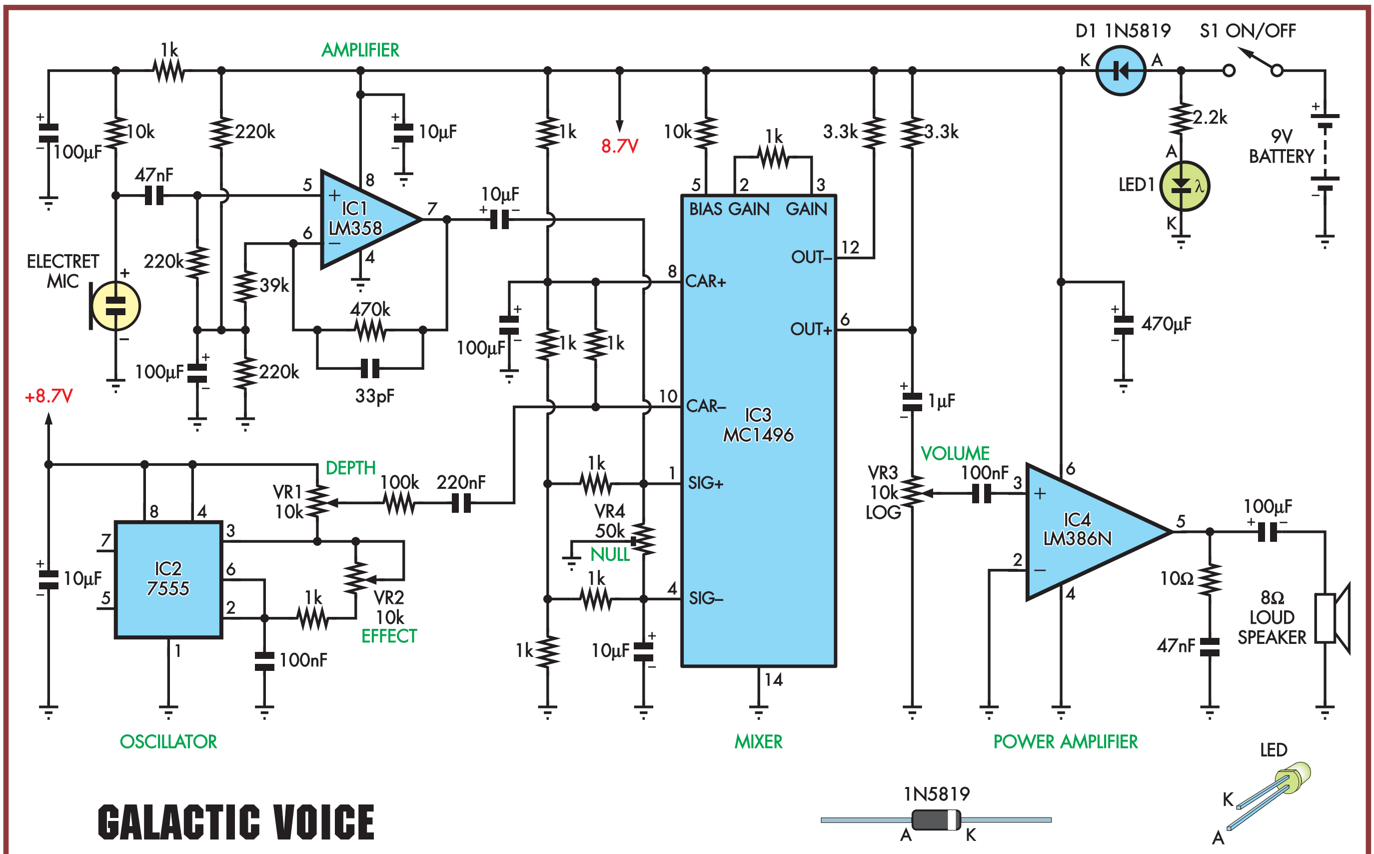


Fig.2: the microphone signal is amplified by IC1, then mixed with a variable square wave from IC2 to produce a modulated square wave, as shown below. IC4 further amplifies the signal to drive a small loudspeaker.

Circuit details

The full circuit diagram for the Galactic Voice is shown in Fig.2. The circuit has just four low-cost ICs, two other semiconductors, three potentiometers, a microphone, a loudspeaker and a few other components.

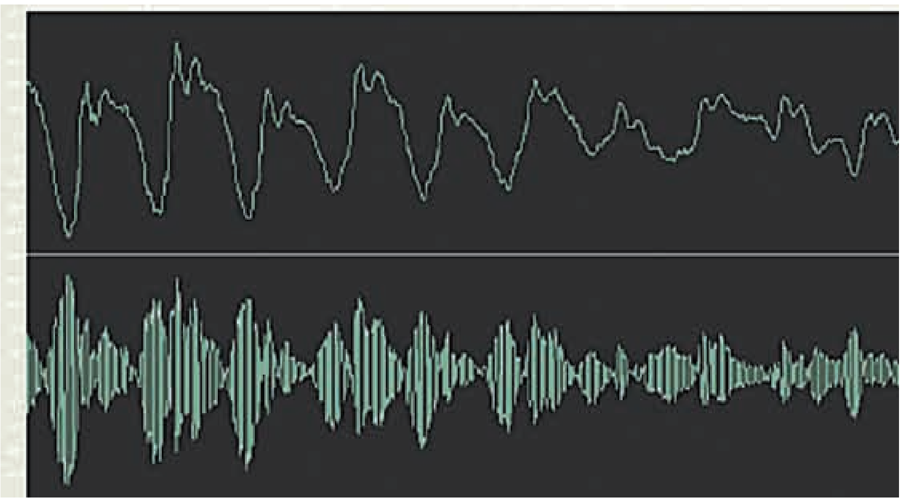
We'll start with the electret microphone. These types of microphones require a power supply; in our case it is derived from the main supply rail via a 1kΩ decoupling resistor and a 10kΩ limiting resistor.

This supply is filtered with a 100µF capacitor to minimise any voltage fluctuations on the main supply (which would happen as the amplifier works hard) from being passed into the sensitive microphone circuitry.

The signal from the microphone is AC- coupled to the non-inverting input of amplifier IC1, one half of an LM358 dual op amp (the other half is not used). It has a gain of about 13, set by the 470kΩ resistor between pins 7 and 6 and the 39kΩ resistor at pin 6. The 33pF capacitor rolls off the amplification above 10kHz to prevent possible oscillation in the amplifier.

Op amp IC1 is biased at close to half the power supply voltage via two 220kΩ resistors connected as a voltage divider across the nominal 8.7V supply. (We'll explain why it is 8.7V shortly).

The resulting 4.35V nominal supply is filtered with a 100µF capacitor. The idea of biasing IC1 at this nominal 4.35V is so that the output is able to swing symmetrically above and below this voltage.



The top waveform is the voice signal, amplified after being received by the microphone. The bottom waveform is at the audio amplifier input and shows the carrier signal modulated by the top waveform

Carrier oscillator

Before we look at where the output goes, let's turn our attention to the carrier oscillator (IC2). This is a CMOS version of the famous 555 timer and is used because it draws far less current than the standard version.

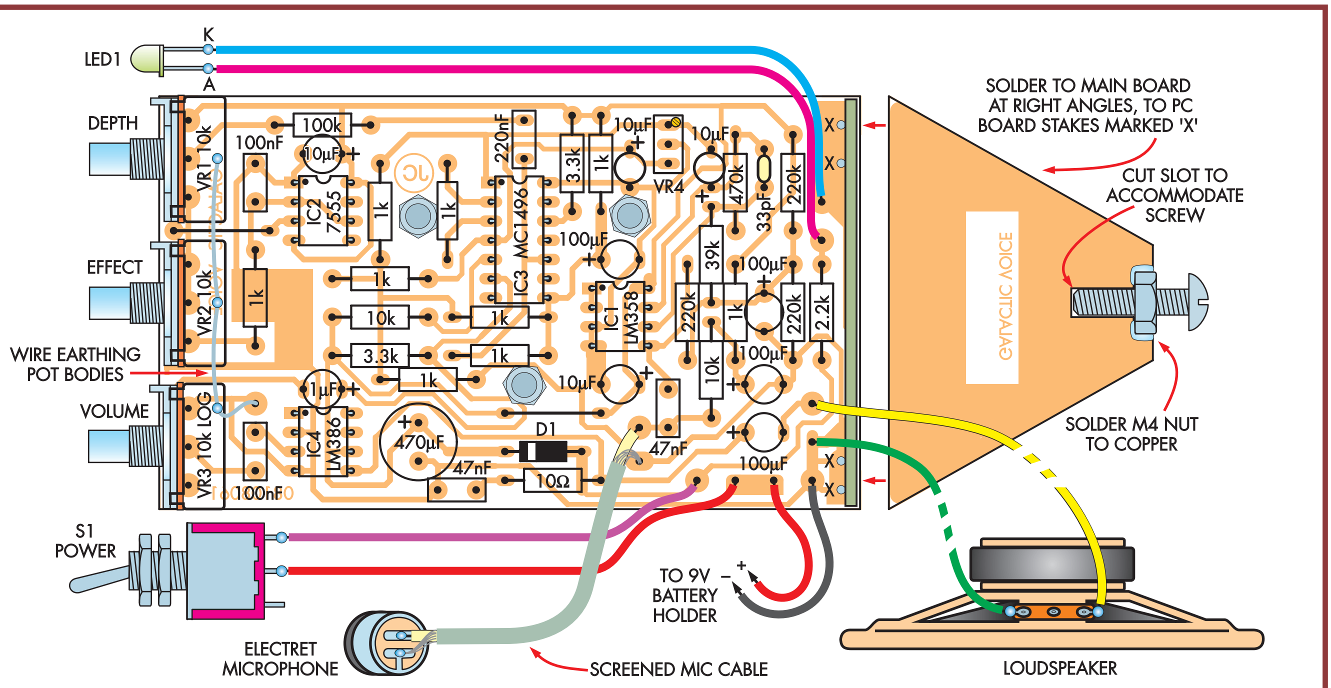


Fig.3: here's how to put it all together – this diagram matches the photo below. The triangular PC board at the right end mounts vertically onto the four PC pins, marked X. This board needs a little 'surgery' first to fit the nut and screw.

The timer is connected to produce a continuous square wave signal and operates as follows: pins 2 and 6 are the threshold inputs that monitor the 100nF capacitor voltage. This capacitor is charged and discharged via variable resistance (potentiometer) VR2 and the 1kΩ resistor, via the output at pin 3.

When charging, pin 3 is high (at the supply voltage) and the capacitor voltage rises. When the voltage reaches two-thirds of the supply voltage (detected by the input at pin 6), pin 3 goes low (at 0V).

The 100nF capacitor now discharges until the voltage reaches one third of the supply voltage (detected at pin 2). Pin 3 goes high again to recharge the capacitor. The process continues and a square wave is produced at pin 3. The frequency can be set to between 655Hz and 7.2kHz by varying VR2.

Potentiometer VR1, connected between the pin 3 output of IC2 and the 8.7V supply rail, provides control over the carrier level.

With the wiper (moving contact) of VR1 wound fully toward the 8.7V end, there will be no output signal. As VR1 is wound down, an increasing amount of square wave from pin 3 will pass through, with the full signal available when the wiper is turned fully toward the pin 3 end of the potentiometer.

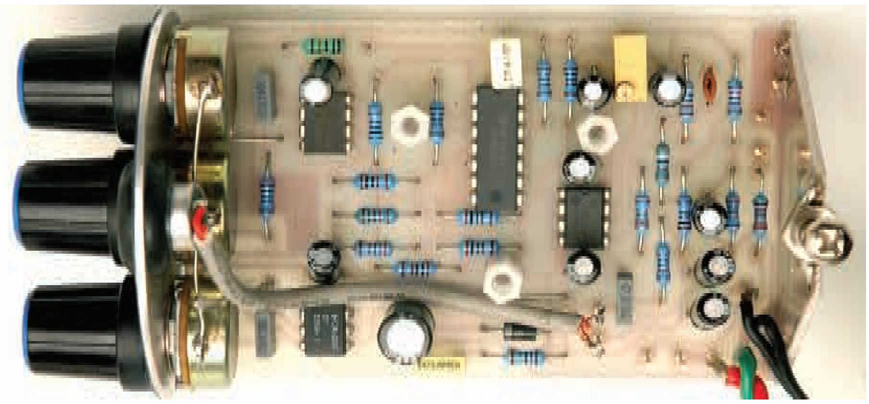
Control VR1, therefore, provides a depth control of the modulation. The 100kΩ resistor in series with the wiper limits the modulating level to a maximum of around 50mV, thus preventing overload at the maximum setting of VR1.

Into the mixer

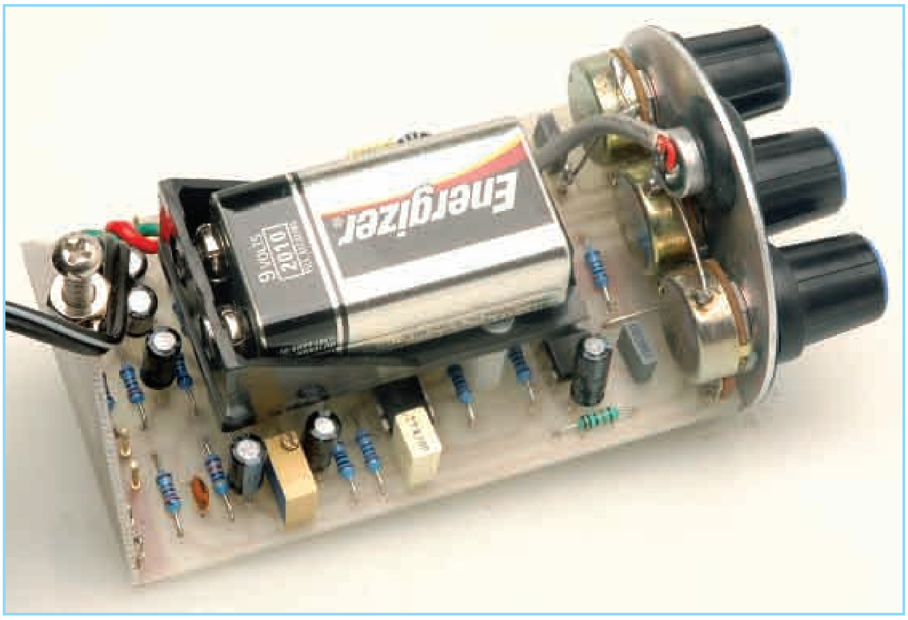
The output of IC1, taken from pin 7, is AC-coupled to the signal '+' input of the mixer (IC3) at pin 1. The signal '–' input (pin 4) is coupled to ground via a 10µF capacitor. Because of this, the signal is only applied to the signal '+' input.

At the same time, the output from IC2, taken from pin 3 via the Depth control, is AC-copuled (via 220nF) to the CAR– input (pin 10), with the CAR+ input (pin 8) also AC-coupled (100µF) to ground.

There are three 1kΩ resistors forming a resistive divider between the 8.7V supply rail and ground. Pins 1 and 4 of IC3 connect (via 1kΩ resistors) to the lower resistor in this divider network. Trimpot VR4 allows the circuit to be balanced. Balancing removes the carrier signal from the mixer output when there is no applied signal at the signal '+' input.



This photo, reproduced close to life size, shows the populated PC board before the battery holder is screwed onto the three standoffs (the white hexagonal pillars). The M4 screw (right end) would normally not be inserted until after the assembly is placed inside its plastic tube 'case' – we left it there because we didn't want to lose the screw!



The completed assembly, ready to slide into the speaker port tube. The two apparently unused PC stakes at the very left of the board are for the control panel LED and are actually soldered underneath the PC board – see Fig.4.

This shows how the support PC board is attached to the main board. . .

. . . while this shot shows the underside of the control panel with power switch and LED.

The carrier signal is applied to the pin 10 input, which is biased to the top 1kΩ resistor in the divider string and the voltage is decoupled with a 100µF capacitor. The carrier '+' input is also fixed at this bias voltage.

The mixer outputs (pins 6 and 12) are biased with 3.3kΩ resistors to the 8.7V supply. The 10kΩ resistor from pin 5 of IC3 sets the overall bias of the mixer and the 1kΩ resistor between pins 2 and 3 sets the mixer gain.

The output from the mixer (pin 6) is coupled, via a 1µF capacitor, to Volume control VR3. This adjusts the level of signal applied to the power amplifier (IC4).

The amplifier drives the 8Ω loudspeaker, via a 100µF capacitor, which blocks the DC component from IC3's output. The 10Ω resistor and 47nF capacitor at IC4's output provides a substantially capacitive load at higher frequencies to prevent the amplifier from oscillating.

Protection

The circuit is powered by a 9V battery, controlled by power switch S1. As you no doubt realise, it is far too easy to reverse-connect a 9V battery, which can – and often does – let the smoke out of semiconductors. So diode D1 prevents current flow if the battery is connected the wrong way around.

The diode deserves special mention: it is a Schottky type, not a normal silicon variety. Schottky diodes have a voltage drop about half that of silicon diodes (0.3V vs 0.6V), thereby maximising battery life.

The main supply is therefore a nominal 8.7V, due to the 0.3V drop

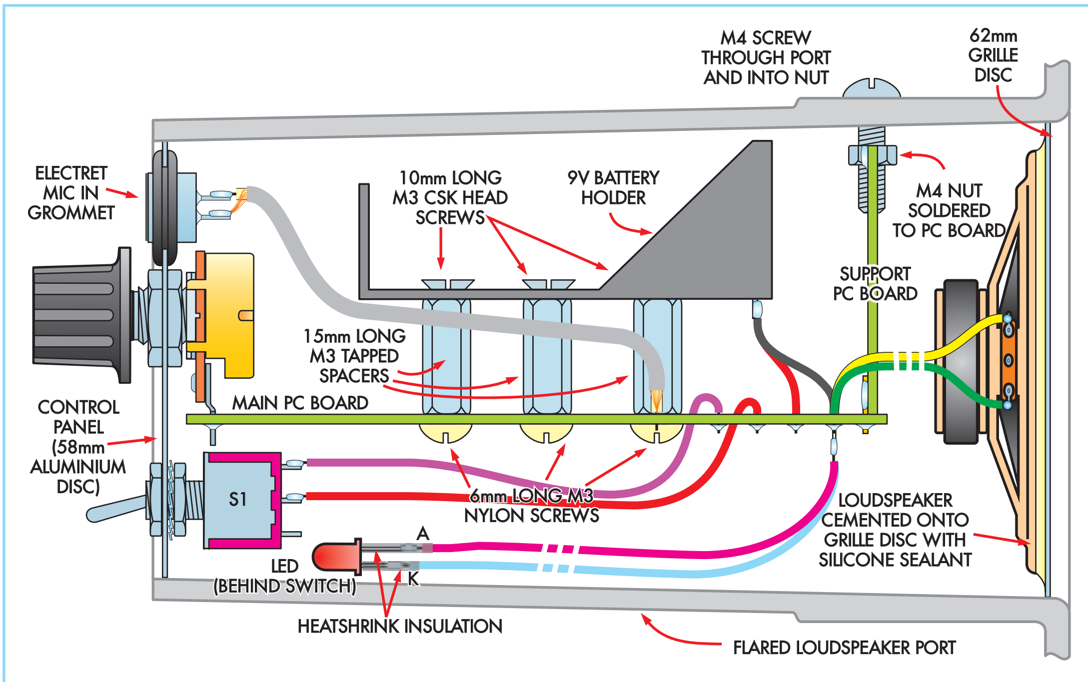


Fig.4: the whole assembly slides into the speaker port 'case' from left to right (the speaker 'baffle' disk is already glued in place with silicone sealant). Take care that you don't crimp or catch the speaker wiring (which is actually much longer than shown here) as you slide it in. When in the right place, the control panel will be right at the open end of the port tube and the M4 nut will be level with the hole in the port side, ready for the M4 screw to be inserted and tightened.

across D1. LED1 is included to indicate power is on. Overall current drain is less than 14mA with a 9V battery, which should give about 300 hours of battery life with a fresh alkaline battery and intermittent use.

Construction

Most components for the Galactic Voice are assembled onto a 93 × 55mm PC board, *EPE* code 674, plus the trapezoid-shaped, 34 × 55mm, section of the board, used as a support for the assembled project. This board is available from the *EPE PCB Service*. The board component layout is shown in Fig.3, and the PCB copper masters in Fig.7.

An M4 nut is soldered to the top of the support PC board, with a matching hole drilled near the flared end of the plastic tube. An M4 screw passes through this hole into the nut, securing the Galactic Voice components board in place inside the tube. The flared plastic speaker port tube measures 58mm diameter × 120mm long.

An aluminium disc is used as the support for the loudspeaker and is secured to the flared end of the tube using silicone sealant. This is 62mm diameter and has holes drilled to make a speaker grille (see Fig.5b).

The opposite end of the tube has a similar, though smaller, aluminium disk (58mm diameter) drilled to accept the potentiometers, the switch and LED bezel and for the microphone mounting grommet (Fig.5a).

Circuit board

Begin PC board construction by checking for any shorts or break in the copper tracks. Defects in boards these days are rare, but if you find any, repair them now to avoid problems at a later stage.

Shorts between tracks can be fixed by scraping between the tracks with a sharp hobby knife. Breaks in tracks can be connected with a layer of solder, with a short length of wire acting as a 'bridge' if necessary.

Insert the low-profile components first, such as the two wire links, the diode, the resistors and the ICs. Use the resistor colour code table to help find each value of resistance, and/or check the value using a digital multimeter.

Take care when installing the polarised components (eg, all semiconductors (including ICs) and electrolytic capacitors). Ensure they are oriented correctly and in the correct position.

Parts List – Galactic Voice

1 PC board code 674, available from the *EPE PCB Service*, size 93 × 55mm; plus support board 34 × 55mm
1 flared speaker port tube, 58mm inside diameter × 120mm long (Jaycar CX-2688 or equivalent)
1 57mm diameter 8Ω loudspeaker
1 miniature electret microphone insert
1 1mm aluminium disc, 62mm diameter
1 1mm aluminium disc, 58mm diameter
1 9V PC mount battery holder
3 knobs to suit potentiometers
1 SPDT toggle switch (S1)
1 rubber grommet, with 9.5mm (ID) hole – see text
1 5mm LED bezel clip
3 M3 tapped x 15mm spacers
3 M3 x 10mm countersunk screws
3 M3 x 6mm nylon screws (or cut down longer screws)
1 M4 x 15mm screw and nut (brass preferable – see text)
1 50mm length of single-core shielded cable
1 400mm length of medium-duty hookup wire
1 200mm length of light-duty figure-8 speaker wire
1 50mm of 3mm heatshrink tubing
1 60mm length of 0.7mm diameter tinned copper wire
1 150mm cable tie
15 PC stakes

Semiconductors
1 LM358 dual op amp (IC1)
1 7555 CMOS 555 timer (IC2)
1 MC1496 balanced mixer (IC3)
1 LM386 1W power amplifier (IC4)
1 1N5819 Schottky diode (D1)
1 5mm red LED (LED1)

Capacitors
1 470µF 16VW PC electrolytic
4 100µF 16VW PC electrolytic
4 10µF 16VW PC electrolytic
1 1µF 16VW PC electrolytic
1 220nF MKT polyester
2 100nF MKT polyester
2 47nF MKT polyester
1 33pF ceramic

Resistors (0.25W 1% carbon or metal film)

1 470kΩ	3 220kΩ	1 100kΩ	1 39kΩ	2 10kΩ
2 3.3kΩ	1 2.2kΩ	9 1kΩ	1 10Ω	

2 10kΩ linear 16mm PC mount potentiometers, (VR1,VR2)
1 10kΩ log 16mm PC mount potentiometer (VR3)
1 50kΩ multi-turn top adjust trimpot (VR4)

Miscellaneous
Silicone sealant (non-acid cure), black paint

Solder the components in position and cut the 'pigtails' from the resistors and links from the underside of the PC board with fine, sharp sidecutters.

Now insert the PC solder stakes. These are located at all the external wiring points and at the four mounting points for the second PC board, at the right-hand edge of the main PC board.

Finally, solder in all other on-board components.

Before installing the potentiometers, cut their shafts to length to suit the knobs you are using. Now install the pots, taking care to place the 10kΩ log potentiometer in the volume position.

(Left): this view shows the business end of the Galactic Voice with a small speaker glued inside the 'grille'. The 'case' is a speaker tuning port, which just happens to be the right size!

(Right): here's the opposite end. The microphone is located inside the grommet (top) while the three controls are Effect, Depth and Volume. The LED shows that power is switched on.

The pots must be earthed to the 0V rail on the PC board with a linking wire from the 0V PC stake soldered to each pot body.

The coating on the pot does not take solder easily – almost certainly, you will need to scrape it away where it is to be soldered to ensure a good attachment for the wire.

The hardware

The PC support board requires cutouts to allow the M4 nut to be soldered to the board and also a notch to allow the matching M4 screw to insert into, and through, the nut. These cutouts are the non-copper areas shown on the PC board. They can be cut out with a drill and hacksaw and finished with a fine file.

Solder a brass M4 nut to the top edge of the support PC board as shown. When you solder the nut onto the PC board make sure the inside thread is not soldered.

Fig.5 shows the holes and sizes for the control panel and the speaker 'grille' discs. These are made from 1mm aluminium sheet offcuts. Cut out the circle shapes with tinsnips or a hacksaw and file to shape. The front (62mm) disc requires a series of holes, as shown, to allow the sound to escape from the loudspeaker.

We painted the outside face of our grille black using a spray can. When the paint was dry, the loudspeaker was secured to the grille with a smear of silicone sealant around the speaker rim.

Wire up the loudspeaker using a 170mm length of mini figure-8 speaker wire and secure it around the magnet on the loudspeaker with a cable tie. This will ensure a tug on the wires doesn't break off the lugs on the loudspeaker.

Attach the speaker grille and loudspeaker assembly to the inside of the flared end of the port using silicone sealant.

Next, we need to attach the control panel label (Fig. 6) to the control panel disc and cut the holes out through the panel with a sharp knife.

Place the power switch, the LED bezel and LED in position and insert the rubber grommet in the microphone hole.

Wire the microphone, using *shielded* audio/mic. cable and then insert the microphone into the rear of the grommet.

Attach the control panel to the PC board and secure it using the potentiometer nuts. Solder the microphone lead to the top side of the PC board (PC stakes) and the LED and switch direct to the appropriate copper pads on the underside of the PC board.

The 9V battery holder is mounted on 15mm-long standoffs and M3 screws, as shown in Fig.4. The three mounting holes in the battery holder are drilled out to 3mm (or 1/8in.) and counter-bored to suit the M3 countersunk screws.

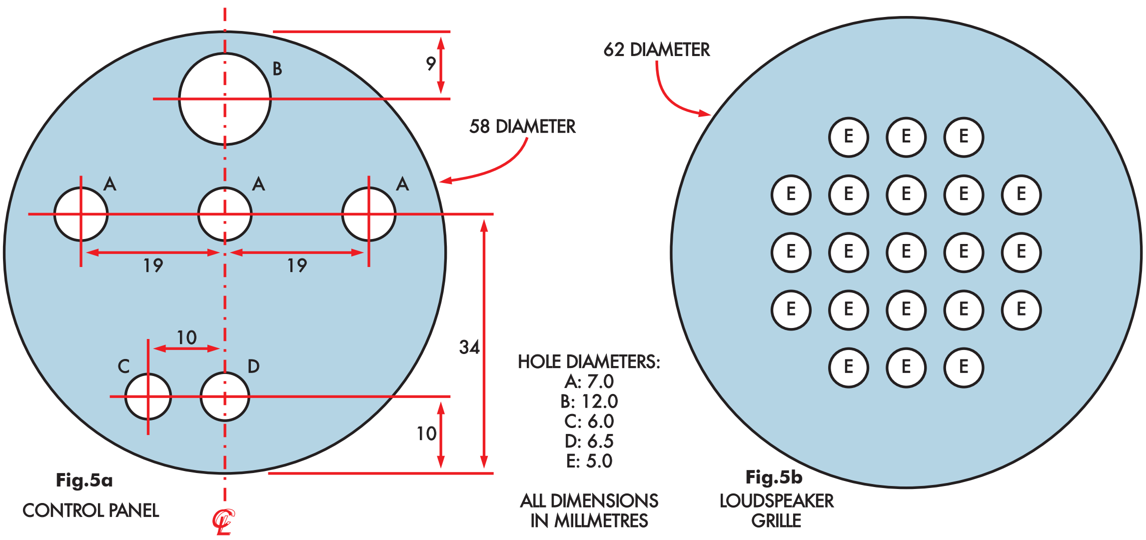


Fig.5: the drilling detail for the front (control) panel (Fig.5a, left) and the rear (speaker baffle) panel (Fig.5b, right). Note that these 1mm aluminium discs are different sizes.

Resistor Colour Codes

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❏	1	470kΩ	yellow violet yellow brown	yellow violet black orange brown
❏	3	220kΩ	red red yellow brown	red red black orange brown
❏	1	100kΩ	brown black yellow brown	brown black black orange brown
❏	1	39kΩ	orange white orange brown	orange white black red brown
❏	2	10kΩ	brown black orange brown	brown black black red brown
❏	2	3.3kΩ	orange orange red brown	orange orange black brown brown
❏	1	2.2kΩ	red red red brown	red red black brown brown
❏	7	1kΩ	brown black red brown	brown black black brown brown
❏	1	10Ω	brown black black brown	brown black black gold brown

Nylon screws are used beneath the PC board to prevent shorting the tracks. They can be cut down to 6mm using side cutters. Before mounting, bend the output terminals inward flat against the underside of the holder and solder hookup wire to each terminal. Now attach the holder in place. Wire the speaker wires to the PC stakes and the battery holder wires to the PC board, taking care to make the correct polarity for the connection.

Solder the support PC board at right angles to the main PC board – it solders to the four PC stakes located at the end of the PC board.

A 4mm hole is required to be drilled on the side of the speaker port tube at the flared end, 95mm from the non-flared end. This is for the M4 screw to be screwed into the M4 nut on the support PC board.

Checkout time

Insert the 9V battery and check that the Galactic Voice works by switching on power. The power LED should light and a squeal should come from the loudspeaker if the volume is wound up.

Needless to say, that's feedback caused by the microphone and speaker being in close proximity. But that feedback can also be used to give even more variety to the sound output, especially if adjusted until *just before* audible feedback commences.

Try speaking into the microphone and adjust the Effects and Depth pots to see if they are working.

If the LED doesn't light or if you aren't getting any output, first check the polarity of the wiring. You should also check the parts on the PC board for correct placement and correct orientation for the polarised parts.

Having said that, about 99% of faults in projects are due to soldering problems – particularly 'dry joints' – so if you aren't having any joy, check your soldering again!

Check that power is available between pins 4 and 8 of IC1, pins 1 and 4 of IC2 and pins 4 and 6 of IC4. A fresh battery should give 8.7V across each of these sets of pins.

The Null control (VR4) is adjusted when VR1 is wound to its maximum (fully clockwise) and the volume turned up, but not so high that there is feedback. Adjust VR4 so that no tone can be heard when there is no noise present at the microphone.

Finally, when it all works correctly, the assembly can be slid into the rear of the tube. Note that the speaker wire needs to be kept tight when sliding in so it does not become caught between the rear of the speaker and the support PC board. The wire is tucked in behind the volume potentiometer.

Secure the assembly by screwing the M4 screw into the support PC board's M4 nut after you have lined the two up.

Fig.6: the front panel label we used for the Galactic Voice. A colour copy or printout can be glued to the disc.

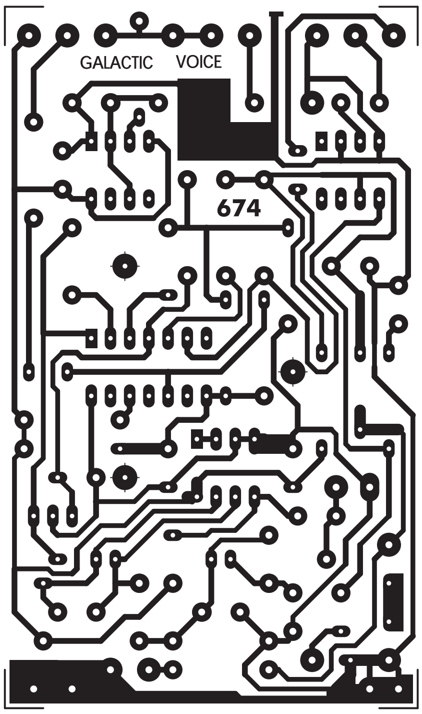


Fig.7: 1:1 artwork for both of the PC boards with the support PC board at bottom. Note the cutouts needed in this board.

nuqneH! – if you don't understand what that means, you really need to brush up on your Klingon – otherwise you might make a mistake and be exterminated! ***EPE***

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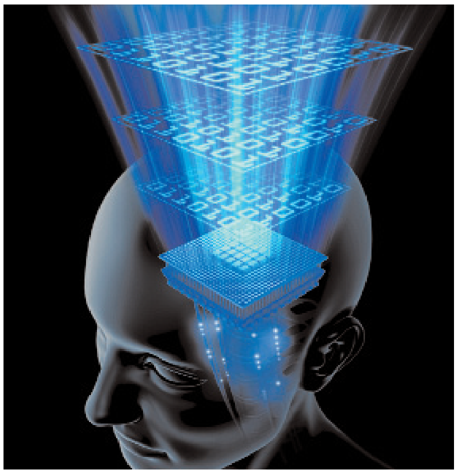
Teach-In 2008

Part Nine – Watchdog Timer, Sleep and Interrupts, plus simple value converter



JOHN BECKER

This month we show you how to use three important PIC facilities – the Watchdog Timer (WDT), Sleep and Interrupts.

The purpose of a PIC's Watchdog Timer (WDT) is to give the PIC a type of protection against becoming stuck in a perpetual loop. This can happen in several ways, but particularly in the event of unforeseen program errors, or waiting for an external event to happen, but which never does (for many and varied reasons, including equipment malfunction). It is also possible for electrical spikes on power lines to cause the malfunction, although it can be argued that the use of a good power supply should be mandatory in situations where this could be an unacceptable problem.

In effect, the WDT provides a 'last-ditch' time-out timer which, if it is allowed to time-out, causes a complete system reset. The idea is that the WDT is set with a prescaled timing value, and then at regular intervals in the main loop of the program, this value is repeatedly reloaded into it, ie it is reset, using the command CLRWDT. Should a problem occur which prevents the WDT value from being reloaded, the WDT will time-out and cause a full program reset.

The difficulty of using a WDT in many programs is that when the full reset occurs, any variables which are specifically set to known values at the start of the program will once more be reset to them. This means, for example, that event counters within the program will also be reset.

When the existing count value is of importance, rather than use the WDT, the program should be written so that an interrupt (from a switch, for instance) can cause the program to resume running without being reset. However, if it doesn't matter that the program restarts from the beginning, as in some burglar alarm systems perhaps, then the WDT can be beneficially used.

To use the WDT, the PIC has to be set for this function through the Config code. In this case, where the internal 4MHz oscillator is used, the equivalent code for WDT to be turned on is **__config h'3F34'**, as you will see near the head of the demo program.

The rate of WDT time-out is governed by the setting of bits 0 to 2 of the OPTION_REG. The WDT is initially cleared at the same time while still in BANK1:

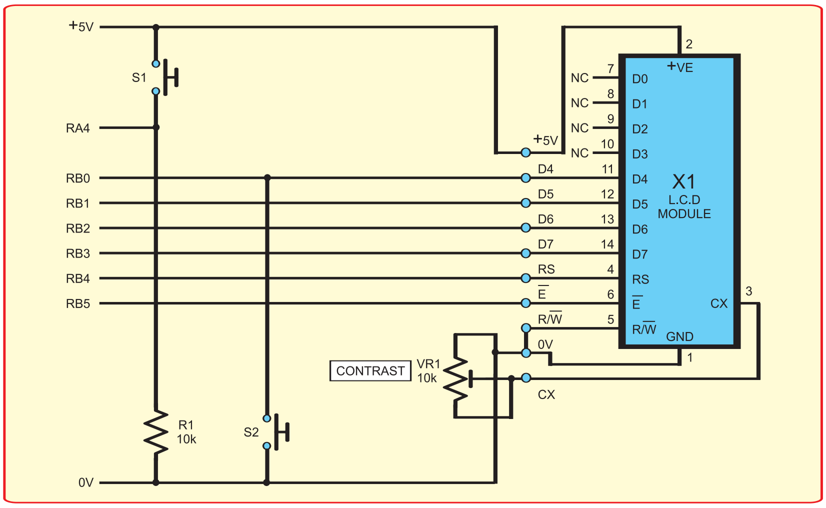


Fig. 9.1. Circuit for WDT and Sleep demos

```
MOVLW b'00001111'
; allocate prescaler for WDT (bit 3 = 1)
; with slowest timer 1:128 (bits 0-2)
MOVWF OPTION_REG
CLRWDT
; clear watchdog timer
BANK0
```

The main part of the program, starting at TESTON, is shown in Listing 9.1. The call to PAUSIT is to make the count rate more visible. Assemble the circuit as shown in Fig.9.1 and Fig.9.2. Switch S1 is used for this demo. Load the program's hex file, **TEACHINJ01.hex**, and run it.

Watch it!

Observing the count on the LCD, you will see that the count never really gets very high because WDT is not being reset, and so timing out and resetting the program. However, if you periodically press switch S1, WDT is reset and the count continues upwards. Should you not press S1 fast enough, the WDT will time-out and restart the program from the beginning, causing the count to be reset to zero.

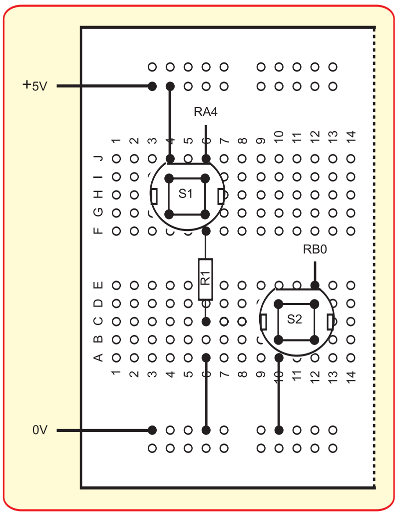


Fig. 9.2. Breadboard layout for Fig.9.1

The WDT timing period can be changed in the same way that we set the timing prescaler for the TMR0 real-time clock, ie using bits 0 to 2 of OPTION_REG. Bit 3 of OPTION_REG must always be set so that the prescaler is allocated to the WDT.

Listing 9.1

```
TESTON      incfsz COUNTER0,F      ; inc Counter value
            goto TSTOFF
            incfsz COUNTER1,F      ; inc Counter value
            goto TSTOFF
            incfsz COUNTER2,F      ; inc Counter value
            goto TSTOFF
            incf COUNTER3,F        ; inc Counter value

TSTOFF      movf COUNTER0,W
            movwf REGA0
            movf COUNTER1,W
            movwf REGA1
            movf COUNTER2,W
            movwf REGA2
            movf COUNTER3,W
            movwf REGA3

            call BIN2DEC
            call LCD1
            bsf RSLINE,4
            call SHOWDIGIT1
            btfsc PORTA,4
            CLRWDT
            call PAUSIT
            goto TESTON            ; repeat the procedure
```

Listing 9.2

```
MAIN        call SHOWIT            ; (decimalisation and display)
            incfsz COUNTER0,F      ; inc Counter value, is it = 0?
            goto MAIN              ; no

            BANK1                  ; yes
            movlw 1                ; set RB0 for input
            movwf TRISB
            BANK0

            MOVLW b'00010000'
            MOVWF INTCON           ; set bit 4 to enable external interrupt
            SLEEP                  ; now go to sleep and wait till RB0 switch
                                   ; is pressed
            BCF INTCON,1           ; clears ext interrupt flag after end sleep
            BANK1
            clrf TRISB             ; set PORTB for LCD use
            BANK0

            incfsz COUNTER1,F      ; inc Counter value
            goto MAIN
            incfsz COUNTER2,F      ; inc Counter value
            goto MAIN
            incf COUNTER3,F        ; inc Counter value
            goto MAIN
```

The WDT cannot be disabled from within an operational program. It can only be turned off from the PIC configuration command.

An independent RC oscillator is used by the WDT and its timing is unaffected by the frequency of the external oscillator that controls the rest of the PIC.

Try setting different values into bits 0 to 2 of OPTION_REG and observe the count's value on the LCD in respect of the WDT time-out.

Sleep

SLEEP mode sets the PIC into a very low current power-down mode. This can be useful if the PIC is monitoring or controlling something at a very slow rate. In this situation, there are power-saving advantages if the PIC can be put to sleep during periods when it is not required to perform.

The PIC can be awoken from SLEEP by a WDT time-out or through an external interrupt. The program which illustrates the latter is **TeachInJ02.ASM**, as shown in part in Listing 9.2.

The circuit is the same as that for the WDT demo, but uses switch S2 on pin RB0. Load the program and run it.

The program increments a 4-byte counter and outputs the value to the LCD. At each roll-over to the second byte the program is told to SLEEP. It can only be awoken by pressing switch S2, connected to PORTB RB0. Whereupon, the PORTB count resumes, until again it rolls over, falling asleep once more.

There are several important things to note. First, the 'awake' call by S2 operates on the falling edge of the switch press, as set into the OPTION_REG by its bit 6 being set to 0. It would operate on the rising edge of the switch press if bit 6 were set to 1. The current arrangement suits the fact that PORTB pull-ups are on, so that RB0 is normally held high:

```
MOVLW b'00000111'
; set bit 6 for interrupt on falling edge of
RB0 change

MOVWF OPTION_REG
; port B pullups on, bit 7 = 0
```

Bits 0 to 2 of OPTION_REG being set high is to suit TIMER1, which is used in connection with the LCD, as explained in a previous part.

The second point is that TRISB must be set first for the use of the LCD output, and then, once the PIC is asleep, TRISB,0 is set so that RB0 can behave as an input for S2. Once S2 has been pressed, TRISB is again set for LCD use with TRISB,0 being cleared.

The third point is that bit 1 of the INTCON register has to be cleared when the PIC is reawoken. It is set by the action of the PIC being told to sleep.

Interrupts

An Interrupt, as the term implies, literally is an 'interrupt' to the program, causing it to stop what it is currently doing, and perform another action or set of actions, returning to where it left off when the interrupt occurred. Interrupts can be set to occur from several sources, such as a switch or from a trigger pulse generated by another electronic circuit for example.

There are many other interrupt possibilities, as shown in datasheet Fig.14-14 (P104) and Table 14-8 (P106). The function of the bits of the INTCON register are given in its datasheet Table 4.3 (P24). Also see the datasheet for the PIR1 and PIE1 register bit functions.

There are countless situations where interrupts can be put to good use. Let's examine the switch controlled one, and then a timer controlled interrupt. First, the address to which the program must jump when interrupted has to be specified. This is where the opening ORG 4 statement now comes into its own. Following that statement, and prior to the ORG 5 statement, the jump address is inserted. Let's call the jump address ISR, Interrupt Service Routine. So, at the beginning of the program listing we make the following statements:

```
ORG 4
GOTO ISR
ORG 5
```

Since the program, once triggered by an interrupt, automatically jumps to the program address stated, we can simply set up a holding routine which waits until the interrupt occurs, and then the routine specified at the interrupt address is performed. We could actually allow the entire program to be performed without using a holding routine, jumping to the specified routine when the interrupt does occur. This is tricky, though, and can be dangerous to the correct operation of the main program, as will be seen shortly. Allowance has to made for a particular operation to be completed before the interrupt routine is performed. The use of a holding routine can be as simple as:

```
HERE nop
     goto HERE
```

The program would normally be constantly looping through the two commands NOP and GOTO HERE, waiting for an interrupt to occur. On its occurrence, the loop would be exited, and a jump made to the routine at ISR. Obviously, at the end of the routine caused by the interrupt, a return to the program point from where the interrupt jump was made must be specified. There is a command which is used for this purpose, RETFIE.

If we want an external source to generate interrupts, the usual pin used for this purpose is PORTB RB0, designated in the pinout diagram as RB0/INT. (Logic level changes on PORTB RB4 to RB7 are other possible interrupt sources.) To use RB0 as the interrupt source, INTCON bit 4 (INTE) must be set, as follows:

```
MOVLW b'10010000'
MOVWF INTCON
```

INTCON bit 7 (GIE) must, as shown, also be set to enable the global interrupt function. All interrupt bits are named by Microchip and equated as such in the initialising commands brought in via Microchip's .inc file. GIE stands for Global Interrupt Enable.

External interrupt

Suppose now that we want an external interrupt on RB0 to cause PORTA to be incremented. Each time this interrupt occurs, the jump from the holding loop is performed as before. However, it is now INTCON bit 1 (INTF) which is set on the interrupt and has to be cleared before returning to the holding loop, ie BCF INTCON,1 (or bcf INTCON,INTF). Any interrupt monitoring flag must be cleared before that interrupt can occur again.

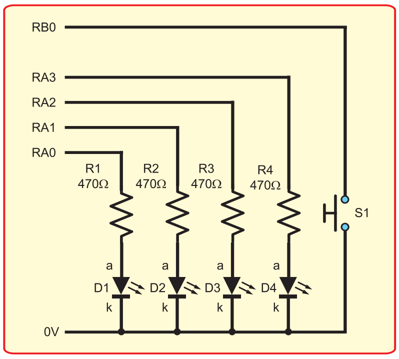


Fig.9.3 Circuit for the Interrupt demo

The circuit needed is shown in Fig.9.3. The interrupt is generated using switch S1. Assemble the breadboard as shown in Fig.9.4.

Load and run **TEACHINJ03.hex** which illustrates this external interrupt.

Since the switch used may be a low-cost type, it is possible that switch-bounce will cause slightly erratic behaviour of the LEDs. It should become clear, however, that the count is basically incremented when the switch is pressed, not when it is released. If a signal generator is connected to RB0 (via a 10k resistor) in place of the switch and monitored on a scope, the triggering edge should be obvious. The signal generator most produce clean 0V to +5V pulses.

As you have seen, INTCON bit GIE (7) is used for enabling (1) and disabling (0) the interrupts, in addition to any other bits required for an interrupt to be enabled. It is possible that at the moment of wishing to disable the interrupts, however, that an interrupt could be in the process of occurring. This would result in the disabling command not taking effect. To ensure that all interrupts are fully disabled (except WDT), the follow routine can be used:

```
DISABL  BCF INTCON,GIE
        BTFSC INTCON,GIE
        GOTO DISABL
```

The main part of the program is shown in Listing 9.3.

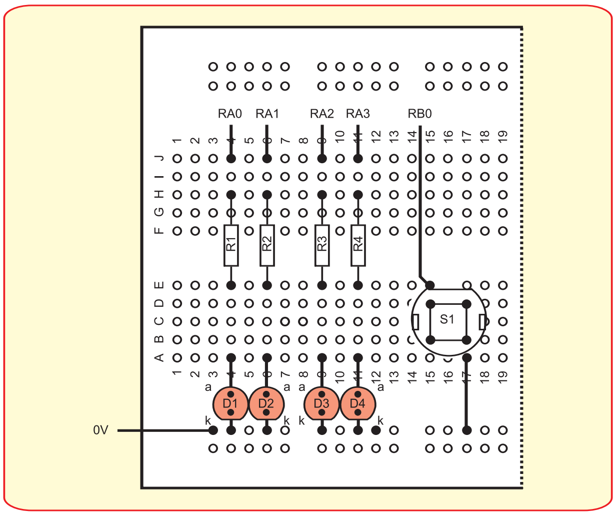


Fig. 9.4 Breadboard layout for Fig.9.3

Having illustrated the use of a switch controlled interrupt, we now show the use of the PIC's TMR0 timer as the interrupt source. That function is in program **TEACHINJ04.asm** and its main part is shown in Listing 9.4, which is a modification of the program shown in Listing 9.3.

The timer is set to its slowest rate via OPTION_REG. The interrupt enabling bits required are GIE and T0IE, as set into INTCON. When the ISR routine is called, the TMR0 overflow flag bit (T01F) must cleared before that interrupt can be responded to again: bcf INTCON,2 (or bcf INTCON,T01F).

Interrupt context problem

There is a significant problem when using interrupts if program registers are being updated when the interrupt occurs. The interrupt could adversely upset the flow of the update. This can be avoided by a simple technique in the ISR routine.

Imagine that we're just entering the ISR: the main program loop has been interrupted. This can happen between any two instructions; exactly where is just a matter of chance depending on exactly when the

Listing 9.3

```
             ORG 0                 ; reset vector
             goto STARTIT
             ORG 4                 ; interrupt vector address
             goto ISR
             ORG 5                 ; PIC program memory location at which
                                   to start

STARTIT      clrf PORTA            ; clear PORTA's outputs if any
             clrf PORTB            ; clear PORTB's output if any
             movlw 7               ; needed by some PICs, including
                                   PIC16F628
             movwf CMCON           ; so that PORTA is treated as digital port

             BANK1                 ; set for Bank 1
             clrf TRISA            ; PORTA as output
             movlw b'00000001'
             movwf TRISB           ; RB0 as input
             clrf OPTION_REG       ; PORTB pull-ups on (bit 7 = 0)
             BANK0
             MOVLW b'10010000'     ; enable GIE (bit 7), RB0 change (bit 4)
             MOVWF INTCON

HERE         nop
             GOTO HERE

TEST         movlw b'11111110'
             movwf PORTB
             goto START

ISR          incf PORTA,F          ; inc LED count
ISR2         btfsc PORTB,0         ; wait switch release
             goto ISR2
             bcf INTCON,1          ; clear RB0 interrupt flag
             RETFIE
```

Listing 9.4

```
          BANK1                ; set for Bank 1
          clrf TRISA           ; PORTA as output
          clrf TRISB           ; RB0 as input
          movlw B'00000111'
          movwf OPTION_REG     ; pullups on (bit 7 = 0), TMR0 slowest rate
          BANK0
          MOVLW b'10100000'    ; enable GIE (bit 7), TMR0 overflow (bit 5)
          MOVWF INTCON

START     nop
          GOTO START

TEST      movlw b'11111111'
          movwf PORTB
          goto START

ISR       incf PORTA,F         ; inc LED count
          bcf INTCON,2         ; clear TMR0 overflow flag
          RETFIE
```

interrupt ocurs. Suppose the interrupt actually happened between the two instructions:

```
B1  xorwf COUNT,W (interrupt occurs
    here)
B2  btfss STATUS,Z
```

The main program has just done an Exclusive-OR of COUNT with W (which holds a value of 10 from the previous instruction MOVLW 10), and is about to go on and test the Z flag in the STATUS register to see if the result was zero (ie COUNT = 10). But in between the ISR will run, and this does an INCF ICOUNT,F instruction. This will overwrite the Z flag. So when the ISR exits, and the main program resumes at the instruction labelled B2, that Z test will be invalid.

Therefore, the ISR must save anything before it changes it, and restore it before it exits.

The bits and pieces that a program uses as working states are often referred to as its *Context*, and so the preamble and postamble in the ISR are called *Saving and Restoring Context*.

The most important items of Context on a PIC are the various flags in the STATUS register, and the contents of the Working register, W, but there may be others. If the ISR uses indirect addressing for example, then it will need to preserve FSR. The preservation of PCLATH may also become important.

The value in the W register can readily be stored, but the Z flag is a problem. Recall that a MOVF instruction could affect the Z flag in the STATUS register, so it cannot be used as part of a context-saving routine. However, the SWAPF instruction does not affect STATUS, so the situation using that instruction is unambiguous. But, of course, STATUS is actually stored in SAVES, with its nibbles reversed. Consequently, on exit the nibbles must be reversed again before being put back into STATUS.

Once W and STATUS have been safely stored, then it's easier to save any other Context items that may need preserving. This is because W and STATUS can now be changed, so there are no constraints on which instructions may be used.

So, for example, to additionally save FSR, the following sequence could be used:

```
ISR    MOVWF SAVEW ; save W
       SWAPF STATUS,W
       MOVWF SAVES ; save STATUS
       MOVF FSR,W  ; OK to use
                   MOVF and
                   change STA
                   TUS here
       MOVWF SAVEF ; save FSR

 (body of the ISR goes here)

 POP   movF SAVEF,W      ; restore
                         FSR
                         movwf
                         FSR
       swapf SAVES,W     ; restore
                         STATUS
       movwf STATUS
       swapf SAVEW,F     ; restore W
       swapf SAVEW,W
       retfie
```

The same would apply to saving PCLATH, and to any other register that also needs to be preserved.

Note that the preservation registers SAVEW, SAVES and SAVEF are user-named registers equated at the head of the program in the usual way.

Maths conversion tool

Space this month allows us to present you with a design that provides conversions between hexadecimal, decimal and binary maths formats. Although PIC assembly programs allow you to specify values in any of these three formats, it can be useful to know how one format translates to another. *TK3* has such a conversion program available as part of its suite of routines.

The design presented now is a simpler version of that, assembled using the components you have been using during this series. The circuit diagram and its breadboard layout are shown in Fig.9.5 and Fig.9.6. Assemble the layout and load the PIC with **TEACHINJ05.hex**.

Switches S1 to S4 change the four nibbles of a 2-byte hex value from left to right, incrementing the value between the 16 values 0-9, A-F. Having reached 15 (F) the value rolls over to 0 again on the next increment. The hex value is displayed on LCD line 1 LHS, prefixed by 'H'. The total hex value is then converted to decimal and displayed to the right of line 1. Then follows a conversion to a 16-digit binary value, displayed on line 2. The process repeats for as long as the respective switch is pressed, but at a rate slow enough to be read easily on the LCD.

Referring to Listing 9.5, the incremented hex digit values aquired in the routines starting at DIG0 are each held in their own register, HEX3 to HEX0. The hex display routine reads the decimal value held in each register (at OUTHEX) and calls a table which returns the symbol (0-F) associated with that value, and sends it to the LCD.

When the full hex value has been displayed, the four hex digits are combined into two registers COUNT1 and COUNT0, using the SWAPF and IORWF commands (at HEXDEC). The COUNT values are then converted to decimal and displayed.

The binary display routine is at HEX2BIN. Here the two COUNT values are rotated left 16 times so that their LH bit rotates into the Carry flag (as previously discussed). The status of the Carry flag is

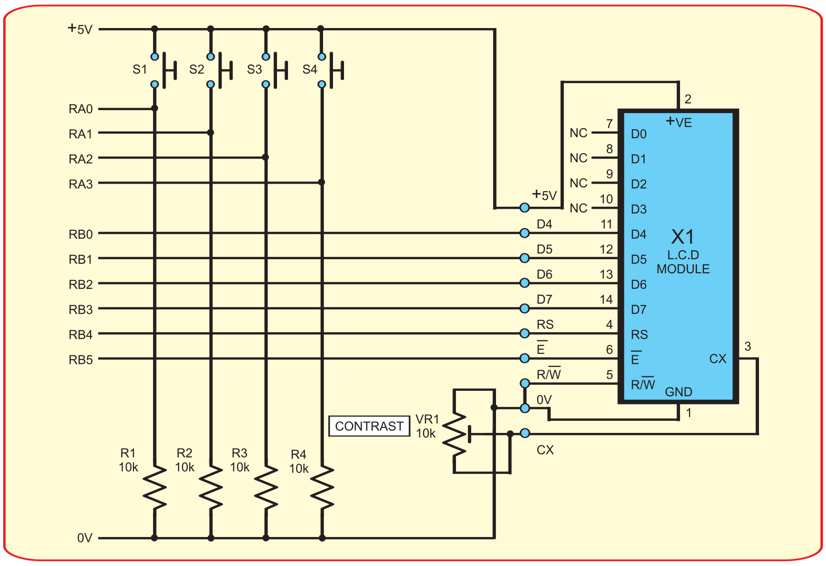


Fig.9.5. Circuit for the maths conversion tool

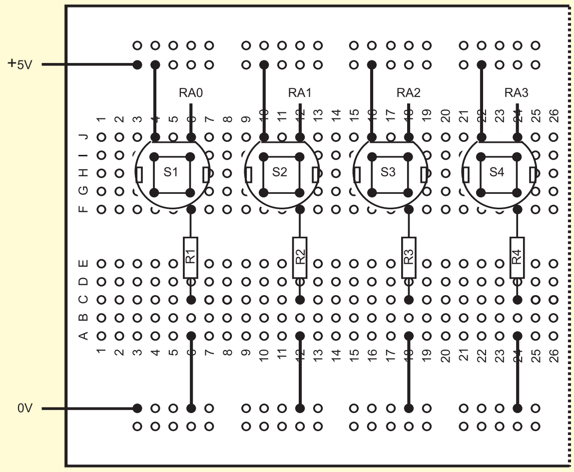


Fig.9.6 Layout for Fig 9.5

then extracted, ORed with 48 to produce its ASCII symbol and sent to the LCD.

Examine the listing to follow the logic. See the ASM file for the full details.

To show the HEX and binary values of a decimal number (up to 63355) press the switches until the required decimal value is shown and then read the other two values shown, likewise for finding what a binary value is in HEX and decimal. Intelligent use of the switches is required! If you overshoot a value, just keep any switch pressed to cycle through the digit values again.

Reference

Programming PIC Interrupts, Malcolm Wiles, March and April 2002. A detailed feature based on the PIC16F84 and PIC16F87x devices.

Listing 9.5

```
; TEACHINY01.ASM 17FEB08 - TEACH IN 2008 PT9

          goto OUTHEX

DIG0      movf PORTA,W
          andlw 15
          btfsc STATUS,Z
          goto DIG0
          clrf LOOP

DIG4      btfss PORTA,0
          goto DIG3
          incf HEX3,F
          bcf HEX3,4
          goto OUTHEX

DIG3      btfss PORTA,1
          goto DIG2
          incf HEX2,F
          bcf HEX2,4
          goto OUTHEX

DIG2      btfss PORTA,2
          goto DIG1
          incf HEX1,F
          bcf HEX1,4
          goto OUTHEX

DIG1      btfss PORTA,3
          goto DIG0
          incf HEX0,F
          bcf HEX0,4
```

Listing 9.5 (Continued)

```
OUTHEX    call LCD1
          bsf RSLINE,4
          movlw 'H'
          call LCDOUT
          movf HEX3,W
          call MESSAG2
          call LCDOUT
          movf HEX2,W
          call MESSAG2
          call LCDOUT
          movf HEX1,W
          call MESSAG2
          call LCDOUT
          movf HEX0,W
          call MESSAG2
          call LCDOUT
          movlw ' '
          call LCDOUT

          call HEXDEC
          call HEX2BIN

          call PAUSIT2
          goto DIG0


HEX2BIN   call LCD21
          bsf RSLINE,4
          movlw 16
          movwf LOOP

HEXDEC    swapf HEX3,W
          iorwf HEX2,W
          movwf COUNT1
          movwf REGA1
          swapf HEX1,W
          iorwf HEX0,W
          movwf COUNT0
          movwf REGA0
          clrf REGA2
          clrf REGA3
          call BIN2DEC
          call SHOWDIGIT5
          return


HEX2BIN2  rlf COUNT0,F
          rlf COUNT1,F
          movf STATUS,W
          andlw 1
          iorlw 48
          call LCDOUT
          decfsz LOOP,F
          goto HEX2BIN2
          return
```

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Our regular round-up of readers' own circuits. We pay between £10 and £50 for all material published, depending on length and technical merit. We're looking for novel applications and circuit designs, not simply mechanical, electrical or software ideas. Ideas *must be the reader's own work* and **must not have been published or submitted for publication elsewhere.** The circuits shown have NOT been proven by us. *Ingenuity Unlimited* is open to ALL abilities, but items for consideration in this column should be typed or word-processed, with a brief circuit description (between 100 and 500 words maximum) and include a full circuit diagram showing all component values. **Please draw all circuit schematics as clearly as possible.** Send your circuit ideas to: *Ingenuity Unlimited,* Wimborne Publishing Ltd., Sequoia House, 398a Ringwood Road, Ferndown, Dorset BH22 9AU. (We **do not** accept submissions for IU via email.) Your ideas could earn you some cash **and a prize!**

Plug n' Play – automatic peripheral detection

THE CIRCUIT in Fig.1 allows a microcontroller, such as a PIC, to detect and identify what external device has been plugged into your circuit. For example, it can differentiate a movement sensor from a temperature sensor, or a pressure sensor, and to which channel (analogue I/O pin), the device is sending its data.

This means the PIC can automatically make the appropriate gain adjustments on the op amps to suit the sensor, and use the correct conversion factors. If your project has an LCD, this can alert the user that your device has discovered your peripheral. Plug n' Play if you like.

How it works

All it takes is for you to place across your peripheral's spare pin (not connected) and ground pin, a resistor (R1), to form a voltage divider when plugged into your circuit (see Fig.1). The device from which you are reading does not have to have four pins, most three pin audio plugs have a (+5V) pin that is not being used.

This voltage is sent to an analogue pin on your PIC. The on-board ADC digitises the voltage, which is then sent to a look up table to tell the PIC which sensor has been plugged in. Just by changing the value of the resistor specific to each peripheral you are able to differentiate between a wide variety of devices. It may mean just having to use only one input socket for your design. Sockets takes up considerable space on a PCB.

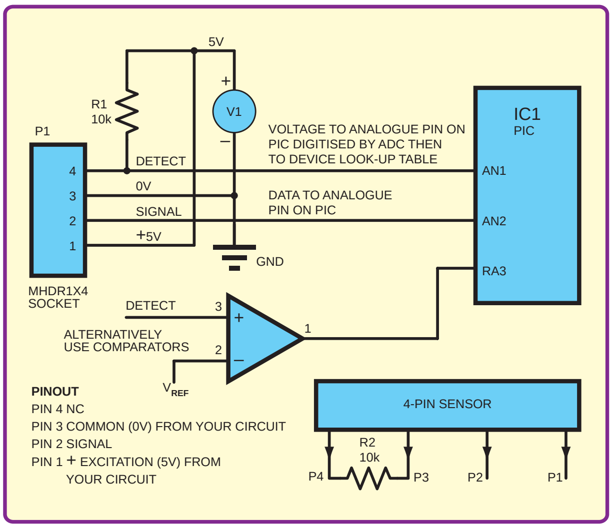


Fig.1. Circuit details for the Plug n' Play peripheral detector

To simplify this further, you could just use your PIC's on board comparators, or add a couple in circuit. However, this would involve using more digital I/O ports.

Peter Barrett, Australia

Temperature Drift Monitoring – *are things getting hotter?*

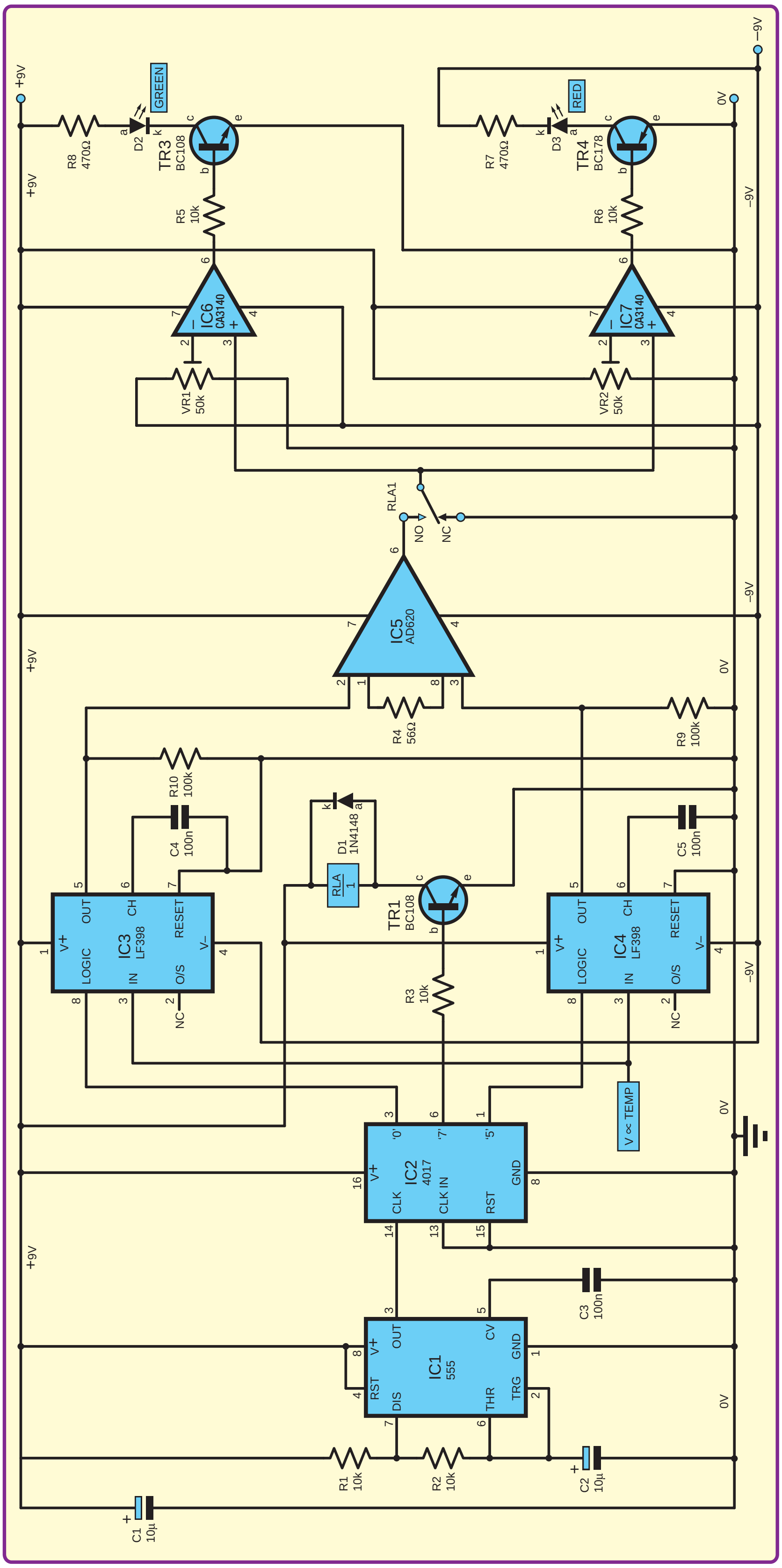


Fig.2. Circuit diagram for the Temperature Drift Monitor

WHEN checking the temperature of semiconductor heatsinks using a probe thermometer, it is useful to have an indicator which shows whether the temperature is rising, steady or even falling.

Several designs have been published for electronic thermometers based on measuring the forward voltage across a silicon diode fed with a constant current. After inversion and amplification this voltage is directly proportional to temperature; samples can be taken in sequence and then compared to discover whether the temperature is going up or down. Fig.2 shows one way of achieving this.

Circuit description

A slow oscillator (IC1) drives a decade decimal counter (IC2) at about 5Hz. IC2's outputs at decimal 0 and decimal 5 enable the two sample-and-hold ICs (IC3 and IC4) in turn, which store the two voltages. A differential amplifier is required to detect and amplify the difference between the samples to determine which is the greater. The difference may be only a few mV, on top of a DC level of several volts, so the amplifier must have a high common-mode rejection ratio (CMRR). This can be achieved with multiple op amps and precision resistors, but a single instrumentation amplifier does a better job, although it is more expensive.

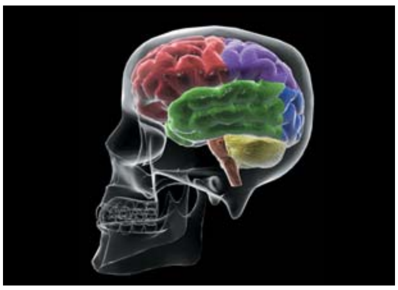
In this case, IC5, an AD620, amplifies the difference with high gain. (The gain is set by resistor R4 at 1+49400/R4.) Its output is positive when the second sample is the greater and negative when it is smaller.

After the second sample has been stored, the count from IC2 switches on TR1, which operates a miniature relay (RLA) connecting IC5's output to the comparators IC6 and IC7. (A relay is used rather than a solid-state switch as the output from IC5 can be either above or below earth and over ranges from a volt or so to the full supply rail potential.)

A repeated positive-going signal, greater than 1V and set by preset VR2, causes the red LED (D3) to switch off and on, showing that the temperature is rising. A negative signal flashes the green LED (D2). Both LEDs will remain on when the temperature is steady.

With the component values shown, quite slow changes in temperature will be sensed, but if a very slow rate of change must be detected then the sample time interval should be lengthened by increasing the value of capacitor C2.

Stephen Stopford, London



Circuit Surgery

Ian Bell

MAX8596X LED driver IC

WE RECEIVED a letter from ***Stephen Else*** in response to the *Circuit Surgery* article in the April issue. He asks about the LED driver circuit using the Maxim MAX8596X:

If two 1.5V AA batteries in series (total 3V) were the supply voltage for the input what would be the output voltage and current? Would the addition of a third battery subsequently provide a one third increase in the output current with this IC?

For the benefit of readers who did not remember the April article, the MAX 8595X is a step-up DC-DC converter with a constant current drive of up to 25mA, for up to nine white LEDs. The typical circuit for the MAX8595X and similar MAX8596X is shown in Fig.1.

Maxim markets these devices for use in LCD backlighting in mobile phones, PDAs, and other handheld devices. Of course, you are not restricted to these uses; LED projects are popular with *EPE* readers and there are plenty of opportunities for innovative LED projects.

The previous article briefly mentioned the MAX8595X as an example of a 'real life' use of a constant current output after discussing the basic theory and fundamental circuits used for current mirrors and constant current sources.

In this article, in response to Stephen's question, we will look at the MAX8595X in more depth. At the same time, we will hopefully provide some insight into circuit design and the use of datasheets that will be of interest to readers who are not contemplating using the MAX8595X at the moment.

LED brightness

In the April article we were discussing uses of constant current sources and discussing the fact that LED brightness is determined by current not voltage. So, if you need even brightness across multiple LEDs then you have to drive the same current through all of them. Using a series connection ensures the LED currents are identical and means that wiring up the LEDs is straightforward.

Driving nine white LEDs in series requires a total of almost 40V, well above the battery voltage of most modern electronic products. The MAX8595X provides a voltage step-up output of up to 36V to facilitate series driving of LEDs, but it is the current through the LEDs which is regulated, not the output voltage. The MAX8595X varies its output voltage to the level required to produce the desired LED current.

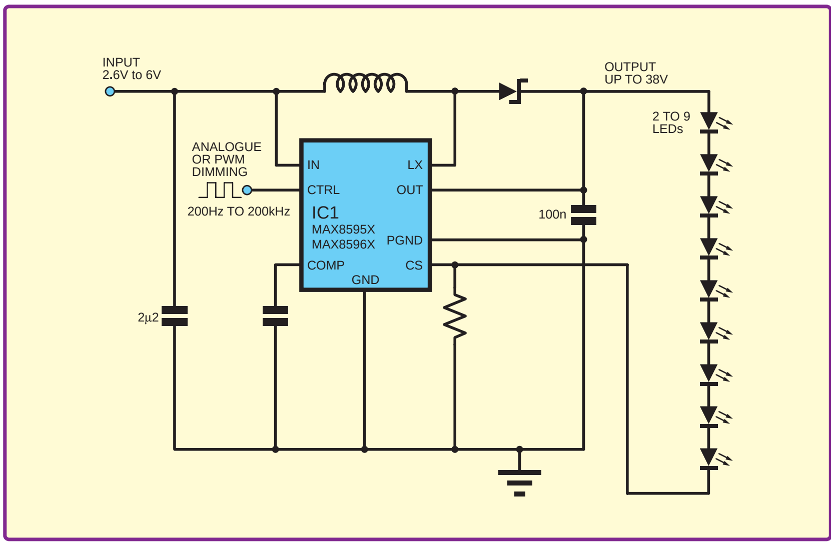


Fig.1. Typical MAX8595X/MAX8596X LED driver circuit.
(circuit from Maxim datasheet – www.maxim-ic.com)

Stephen's question requires us to look into the effect of supply voltage on the operation of the MAX8595X. The first thing to check is the voltage rating. Most datasheets have a section titled 'Absolute Maximum Ratings'. For the MAX8596X we find that for IN to GND (where the battery connects) this is -0.3V to +7V. We would not expect three 1.5V cells to cause any problem with respect to this.

Next, we can look at the normal operating voltages. Typically this information will be found on a datasheet under a heading such as 'Electrical Characteristics'. Here we find that the normal operating supply voltage for the MAX8596X is 2.0V to 6.0V, indicating that either two or three 1.5V cells will be adequate.

To answer Stephen's question we need to know about the operation of the MAX 8596X in more detail. Most datasheets provide an overview of the IC's operation, often with reference to a block diagram of the internal circuitry. The MAX8596X is no exception and provides internal circuit details as shown in Fig.2.

Switch-mode PSU

The MAX8596X contains a switch-mode power supply circuit, switching an inductor (L1) connected to the LX pin with an internal *N*-channel MOSFET. A typical inductor value is 22μH, but the datasheet provides full details of selecting the most appropriate value. The switching frequency is 1MHz, which is generated by an internal oscillator. The switch-mode circuit also requires a high-speed diode (D1); usually this would be a Schottky diode, and again the datasheet provides advice on diode selection.

The switch-mode output voltage is monitored at the OUT pin. This is for over-voltage protection, not voltage regulation. The output voltage of the switch-mode circuit is not directly regulated. When V_{OUT} is greater than 38V, the internal *N*-channel MOSFET turns off until V_{OUT} drops below 36V, then the IC restarts. A 0.1μF (100nF) ceramic capacitor (C1) is required from OUT to ground.

As can be seen in Fig.2, the LED current flows through the sense resistor, R_{SENSE}, to produce a voltage at the CS pin, which is proportional to the LED current. An internal potential divider connected to the CTRL pin (which is at voltage V_{CTRL}) produces a voltage of $V_{CTRL}/5$.

Comparison

This is compared with the voltage on the CS pin to provide a feedback signal to the pulse width modulation (PWM) controller of the switch-mode power supply. A 0.1μF ceramic compensation capacitor C_{COMP} is required to ensure stability of the feedback loop; the datasheet provides additional details on ensuring stability.

The comparison is performed using a differential amplifier, labelled 'g_m' on the block schematic (g_m stands for transconductance). This is known as an error amplifier, because its output is proportional to the difference between the actual and required voltages at the CS pin.

The PWM switcher controller uses the signal from the error amplifier to adjust the switching appropriately in order to regulate the voltage at the CS pin to be equal to $V_{CTRL}/5$. This means the LED current, I_{LED}, is regulated to:

$$I_{LED} = \frac{V_{CTRL}}{5R_{SENSE}}$$

There is a voltage clamp connected to the potential divider which prevents the control voltage at the feedback amplifier exceeding a certain level, hence limiting the LED current. The exact value of this limiting voltage depends on the IC used. The MAX8595X has a fixed limit of 0.33V, using a 1.25V clamp, as indicated in Fig.2, ie 1.25 × 100/(100+379).

The MAX8596X varies the control voltage limit (and hence LED current) according to temperature, preventing overdriving of the LEDs during high ambient temperatures, and also allowing higher currents at lower temperatures.

The value of R_{SENSE} is set according to the maximum LED current, $I_{LED,MAX}$, as follows:

$$R_{SENSE} = \frac{k}{5I_{LED,MAX}}$$

where k is 1.65 for the MAX8595X and 1.72 for the MAX8596X. Typical values are $I_{LED,MAX}$ = 25mA and R_{SENSE} = 13Ω.

The MAX8595X and MAX8596X have a very nice feature which allows the CTRL input to be used for digital PWM control of LED dimming, instead of the analogue control just described. Note, this is a different 'PWM control' from the main switcher controller previously mentioned. The error amplifier and compensation capacitor act as a low pass filter so the LED current is still DC, even when PWM brightness control is employed.

The CTRL pin can also be used to shut down the IC by taking V_{CTRL} below 100mV for more than 8.2ms.

The answer

We are now in a position to answer Stephen's question. The general description of circuit operation tells us that the output voltage is not fixed; it is varied by the device's feedback control circuit in order to produce the desired LED current.

As can be seen from the equations, the LED current is not controlled by the input supply (battery) voltage. It is set by V_{CTRL} and R_{SENSE}. If nothing else is changed, changing the input voltage should not change the output voltage.

As long as the supply voltage is within the normal operating range the LED current will not vary from the value set. Changing from two batteries (3V) to three batteries (4.5V) keeps us within the normal supply range for the device (as already noted) and therefore will not change the LED current, assuming that all other component values and conditions remain the same.

We will now slightly extend Stephen's question by looking a bit deeper into the choice of supply voltage, or more specifically the choice between two or three 1.5V batteries. Which is the best choice?

Efficiency

Many datasheets, particularly for analogue ICs, feature an array of graphs showing how various parameters influence the performance and operation of the chip. These can seem a little daunting when first using datasheets, but they are worth studying as they often provide insights which can help with circuit design decisions. The graphs help you get the most out of the IC; which, of course, is why the manufactures include them.

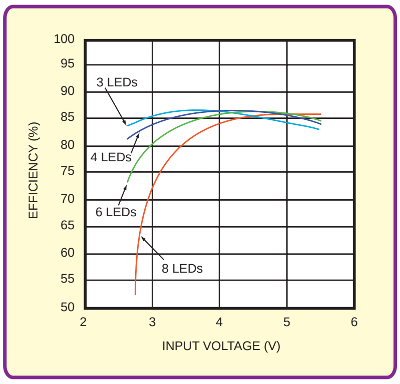


Fig.3. Variation of efficiency with supply voltage for the MAX8595X/MAX8596X (for 25mA LED current)
(Source Maxim datasheet)

There are eight operating characteristic graphs on the MAX8595X/MAX8596X datasheet, and it is the first one which is of most interest to us here. This graph shows the efficiency of the circuit (in %) against supply voltage (see Fig.3). By efficiency we mean the ratio of input power (from the batteries) to LED power (ie (P_{LEDs}/P_{IN})).

The headline efficiency figure on the datasheet is 89%, which is very respectable, but Fig.3 shows that the efficiency is dramatically reduced at low supply voltages, particularly when driving a larger number of

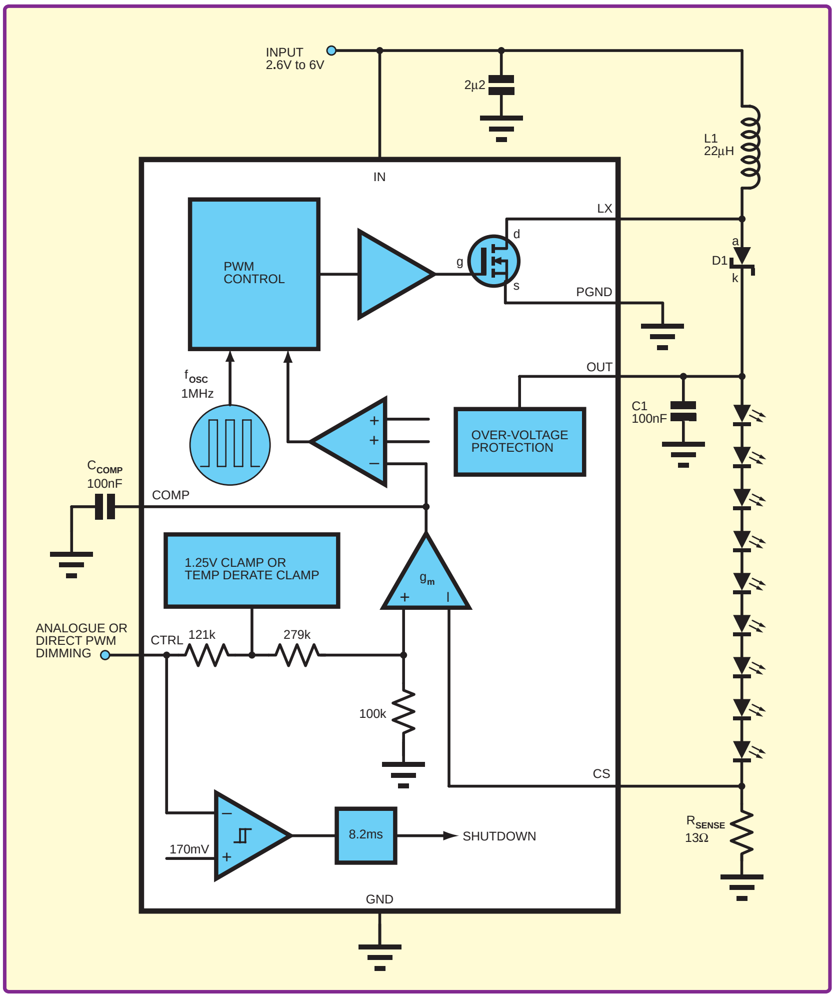


Fig.2. Internal Block Diagram for the MAX8595X/MAX8596X also showing external components used in the typical application circuit.
(circuit from Maxim datasheet)

LEDs. If we end up using the MAX8595X in a low efficiency area of operation we will waste battery power as heat rather than producing light from the LEDs.

To look at battery choice in more depth we need some more details about the batteries. 1.5V is a nominal battery voltage only; the voltage of all batteries varies under different loads and over time as they discharge. Stephen mentioned 1.5V AA batteries, but did not give any further details. We will look at alkaline batteries as an example; other types have different characteristics and could therefore lead to different conclusions.

In Fig.4 is shown the discharge curve for an AA (LR6) alkaline manganese dioxide ($ZnMnO_2$) battery for a current drain of 250mA taken from a Duracell datasheet. Notice that the voltage falls rapidly during initial use and that the voltage is less than 1.4V for most of the service life.

If we used two batteries with these characteristics to power a circuit containing the MAX8595X the supply voltage would be below 2.8V most of the time. Fig.3 shows that this would result in inefficient operation. Using three 1.5V cells of this type would ensure the voltage was above 3.3V for most of the batteries' service life and allow the MAX8595X to run at over 80% efficiency most of the time.

For this type of battery it would seem that three would be better than two, unless any size and weight constraints are very severe. If this was the case, then it might be worth considering different battery technology, or looking for an LED driver IC specified to run from a lower input voltage.

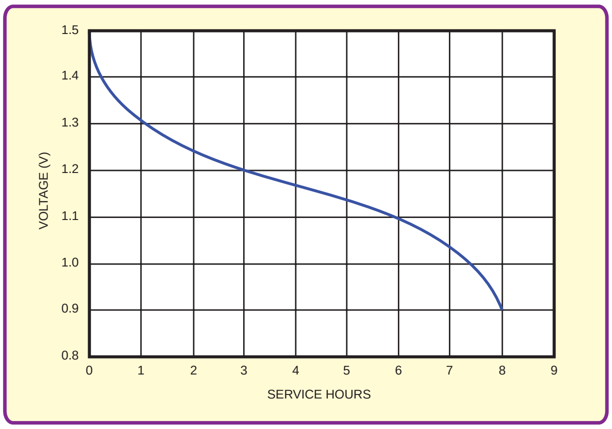


Fig.4. An AA (LR6) alkaline battery discharge curve at 250mA. (based on Duracell datasheet)

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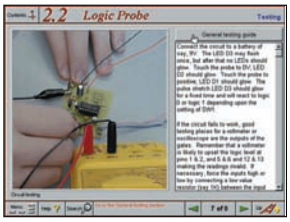
ELECTRONICS CD-ROMS

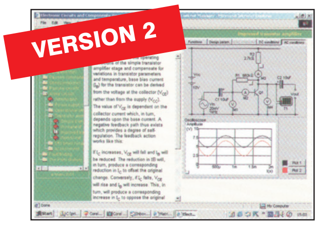
ELECTRONICS PROJECTS



Logic Probe testing

Electronic Projects is split into two main sections: **Building Electronic Projects** contains comprehensive information about the components, tools and techniques used in developing projects from initial concept through to final circuit board production. Extensive use is made of video presentations showing soldering and construction techniques. The second section contains a set of ten projects for students to build, ranging from simple sensor circuits through to power amplifiers. A shareware version of Matrix's CADPACK **schematic capture**, **circuit simulation** and **p.c.b. design** software is included.
The projects on the CD-ROM are: Logic Probe; Light, Heat and Moisture Sensor; NE555 Timer; Egg Timer; Dice Machine; Bike Alarm; Stereo Mixer; Power Amplifier; Sound Activated Switch; Reaction Tester. Full parts lists, schematics and p.c.b. layouts are included on the CD-ROM.

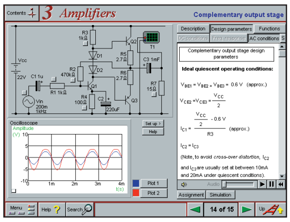
ELECTRONIC CIRCUITS & COMPONENTS V2.0



Circuit simulation screen

Provides an introduction to the principles and application of the most common types of electronic components and shows how they are used to form complete circuits. The virtual laboratories, worked examples and pre-designed circuits allow students to learn, experiment and check their understanding. Version 2 has been considerably expanded in almost every area following a review of major syllabuses (GCSE, GNVQ, A level and HNC). It also contains both European and American circuit symbols. Sections include: ***Fundamentals:*** units & multiples, electricity, electric circuits, alternating circuits. ***Passive Components:*** resistors, capacitors, inductors, transformers. ***Semiconductors:*** diodes, transistors, op.amps, logic gates. ***Passive Circuits. Active Circuits.*** *The Parts Gallery* will help students to recognise common electronic components and their corresponding symbols in circuit diagrams.
Included in the Institutional Versions are multiple choice questions, exam style questions, fault finding virtual laboratories and investigations/worksheets.

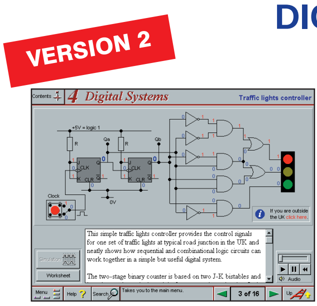
ANALOGUE ELECTRONICS



Complimentary output stage

Analogue Electronics is a complete learning resource for this most difficult branch of electronics. The CD-ROM includes a host of virtual laboratories, animations, diagrams, photographs and text as well as a SPICE electronic circuit simulator with over 50 pre-designed circuits.
Sections on the CD-ROM include: **Fundamentals** – Analogue Signals (5 sections),Transistors (4 sections), Waveshaping Circuits (6 sections). **Op.Amps** – 17 sections covering everything from Symbols and Signal Connections to Differentiators. **Amplifiers** – Single Stage Amplifiers (8 sections), Multi-stage Amplifiers (3 sections). **Filters** – Passive Filters (10 sections), Phase Shifting Networks (4 sections), Active Filters (6 sections). **Oscillators** – 6 sections from Positive Feedback to Crystal Oscillators. **Systems** – 12 sections from Audio Pre-Amplifiers to 8-Bit ADC plus a gallery showing representative p.c.b. photos.

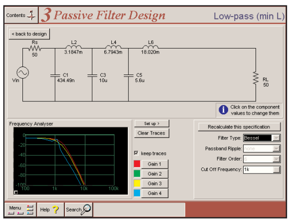
DIGITAL ELECTRONICS V2.0



Virtual laboratory – Traffic Lights

Digital Electronics builds on the knowledge of logic gates covered in *Electronic Circuits & Components* (opposite), and takes users through the subject of digital electronics up to the operation and architecture of microprocessors. The virtual laboratories allow users to operate many circuits on screen.
Covers binary and hexadecimal numbering systems, ASCII, basic logic gates, monostable action and circuits, and bistables – including JK and D-type flip-flops. Multiple gate circuits, equivalent logic functions and specialised logic functions. Introduces sequential logic including clocks and clock circuitry, counters, binary coded decimal and shift registers. A/D and D/A converters, traffic light controllers, memories and microprocessors – architecture, bus systems and their arithmetic logic units. Sections on Boolean Logic and Venn diagrams, displays and chip types have been expanded in Version 2 and new sections include shift registers, digital fault finding, programmable logic controllers, and microcontrollers and microprocessors. The Institutional versions now also include several types of assessment for supervisors, including worksheets, multiple choice tests, fault finding exercises and examination questions.

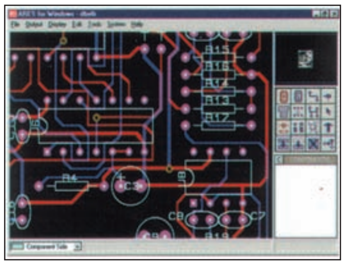
ANALOGUE FILTERS



Filter synthesis

Analogue Filters is a complete course in designing active and passive filters that makes use of highly interactive virtual laboratories and simulations to explain how filters are designed. It is split into five chapters: **Revision** which provides underpinning knowledge required for those who need to design filters. **Filter Basics** which is a course in terminology and filter characterization, important classes of filter, filter order, filter impedance and impedance matching, and effects of different filter types. **Advanced Theory** which covers the use of filter tables, mathematics behind filter design, and an explanation of the design of active filters. **Passive Filter Design** which includes an expert system and filter synthesis tool for the design of low-pass, high-pass, band-pass, and band-stop Bessel, Butterworth and Chebyshev ladder filters. **Active Filter Design** which includes an expert system and filter synthesis tool for the design of low-pass, high-pass, band-pass, and band-stop Bessel, Butterworth and Chebyshev op.amp filters.

ELECTRONICS CAD PACK



PCB Layout

Electronics CADPACK allows users to design complex circuit schematics, to view circuit animations using a unique SPICE-based simulation tool, and to design printed circuit boards. CADPACK is made up of three separate software modules. (These are restricted versions of the full Labcenter software.) **ISIS Lite** which provides full schematic drawing features including full control of drawing appearance, automatic wire routing, and over 6,000 parts. **PROSPICE Lite** (integrated into ISIS Lite) which uses unique animation to show the operation of any circuit with mouse-operated switches, pots. etc. The animation is compiled using a full mixed mode SPICE simulator. **ARES Lite** PCB layout software allows professional quality PCBs to be designed and includes advanced features such as 16-layer boards, SMT components, and an autorouter operating on user generated Net Lists.

ROBOTICS & MECHATRONICS

Case study of the Milford Instruments Spider

Robotics and Mechatronics is designed to enable hobbyists/students with little previous experience of electronics to design and build electromechanical systems. The CD-ROM deals with all aspects of robotics from the control systems used, the transducers available, motors/actuators and the circuits to drive them. Case study material (including the NASA Mars Rover, the Milford Spider and the Furby) is used to show how practical robotic systems are designed. The result is a highly stimulating resource that will make learning, and building robotics and mechatronic systems easier. The Institutional versions have additional worksheets and multiple choice questions.

- Interactive Virtual Laboratories
- Little previous knowledge required
- Mathematics is kept to a minimum and all calculations are explained
- Clear circuit simulations

PRICES

Prices for each of the CD-ROMs above are:

(Order form on third page)

Hobbyist/Student ....£45 inc VAT
Institutional (Schools/HE/FE/Industry)..............£99 *plus* VAT
Institutional 10 user (Network Licence) ....£249 *plus* VAT
Site Licence...£499 *plus* VAT

(UK and EU customers add VAT at 17.5% to "plus VAT" prices)

PICmicro TUTORIALS AND PROGRAMMING

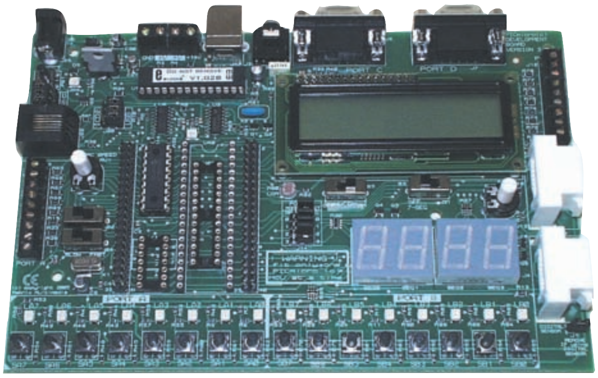
HARDWARE

VERSION 3 PICmicro MCU DEVELOPMENT BOARD

Suitable for use with the three software packages listed below.

This flexible development board allows students to learn both how to program PICmicro microcontrollers as well as program a range of 8, 18, 28 and 40-pin devices from the 12, 16 and 18 series PICmicro ranges. For experienced programmers all programming software is included in the PPP utility that comes with the development board. For those who want to learn, choose one or all of the packages below to use with the Development Board.

- Makes it easier to develop PICmicro projects
- Supports low cost Flash-programmable PICmicro devices
- Fully featured integrated displays – 16 individual l.e.d.s, quad 7-segment display and alphanumeric l.c.d. display
- Supports PICmicro microcontrollers with A/D converters
- Fully protected expansion bus for project work
- USB programmable
- Can be powered by USB (no power supply required)



£158 including VAT and postage, supplied with USB cable and programming software

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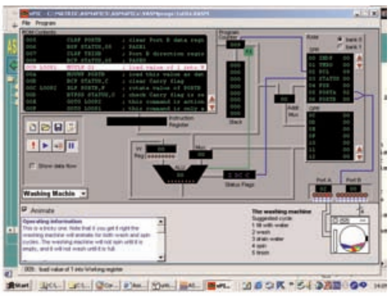
SOFTWARE

ASSEMBLY FOR PICmicro V3

(Formerly PICtutor)

Assembly for PICmicro microcontrollers V3.0 (previously known as PICtutor) by John Becker contains a complete course in programming the PIC16F84 PICmicro microcontroller from Arizona Microchip. It starts with fundamental concepts and extends up to complex programs including watchdog timers, interrupts and sleep modes. The CD makes use of the latest simulation techniques which provide a superb tool for learning: the Virtual PICmicro microcontroller. This is a simulation tool that allows users to write and execute MPASM assembler code for the PIC16F84 microcontroller on-screen. Using this you can actually see what happens inside the PICmicro MCU as each instruction is executed which enhances understanding.

- Comprehensive instruction through 45 tutorial sections
- Includes Vlab, a Virtual PICmicro microcontroller: a fully functioning simulator
- Tests, exercises and projects covering a wide range of PICmicro MCU applications
- Includes MPLAB assembler
- Visual representation of a PICmicro showing architecture and functions
- Expert system for code entry helps first time users
- Shows data flow and fetch execute cycle and has challenges (washing machine, lift, crossroads etc.)
- Imports MPASM files.

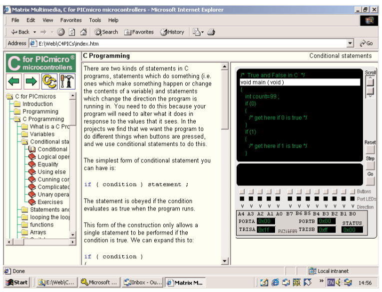


'C' FOR 16 Series PICmicro VERSION 4

The C for PICmicro microcontrollers CD-ROM is designed for students and professionals who need to learn how to program embedded microcontrollers in C. The CD contains a course as well as all the software tools needed to create Hex code for a wide range of PICmicro devices – including a full C compiler for a wide range of PICmicro devices.

Although the course focuses on the use of the PICmicro microcontrollers, this CD-ROM will provide a good grounding in C programming for any microcontroller.

- Complete course in C as well as C programming for PICmicro microcontrollers
- Highly interactive course
- Virtual C PICmicro improves understanding
- Includes a C compiler for a wide range of PICmicro devices
- Includes full Integrated Development Environment
- Includes MPLAB software
- Compatible with most PICmicro programmers
- Includes a compiler for all the PICmicro devices.



Minimum system requirements for these items: Pentium PC running Windows 98, NT, 2000, ME, XP; CD-ROM drive; 64MB RAM; 10MB hard disk space.

FLOWCODE FOR PICmicro V3

Flowcode is a very high level language programming system for PICmicro microcontrollers based on flowcharts. Flowcode allows you to design and simulate complex systems in a matter of minutes. A Powerful language that uses macros to facilitate the control of devices like 7-segment displays, motor controllers and l.c.d.'s. The use of macros allows you to control these devices without getting bogged down in understanding the programming.

Flowcode produces MPASM code which is compatible with virtually all PICmicro programmers. When used in conjunction with the Version 3 development board this provides a seamless solution that allows you to program chips in minutes.

- Requires no programming experience
- Allows complex PICmicro applications to be designed quickly
- Uses international standard flow chart symbols
- Full on-screen simulation allows debugging and speeds up the development process.
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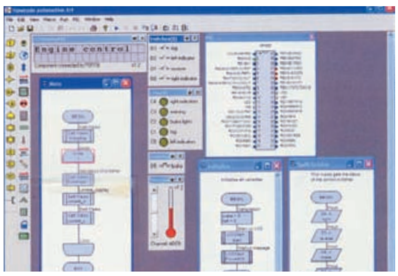

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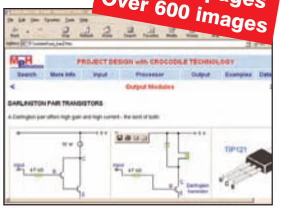

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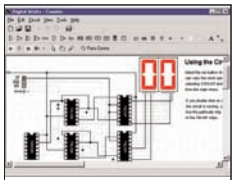

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PIC N' MIX

MIKE HIBBETT

Our periodic column for your PIC programming enlightenment

Microcontroller I/O port expansion

Our thanks to reader **David Gillery** for suggesting this month's article. We explore the subject of *I/O port expansion* – adding extra I/O ports to a microcontroller using an external IC.

We are going to cover this in two consecutive articles, with the first concentrating on device features, and the second demonstrating a practical application – driving a large array of single colour LEDs. Those of you who read the *Chat Zone* forum will probably have guessed that already!

Why port expansion?

So why should we be interested in expanding I/O ports with additional ICs? Microchip provide a vast range of processors, many with a large number of pins. Don't they supply a processor for the job?

There are several reasons why a single microcontroller is not suitable; processors with a large number of pins come in very difficult to solder packages and typically have additional peripheral features that are not required, but add a significant cost. These processors can often be difficult to obtain too. Sometimes, we have to look elsewhere.

Some designs that call for a large number of output pins actually have very simple software requirements which can be achieved with a small, easy to solder and cheap processor – so long as a way to provide the additional I/O pins can be found.

Many IC manufacturers provide solutions to this problem in the form of *Port Expanders* – devices that provide multiple input and output pins with a simple interface designed to be connected to a processor using a standard communication protocol like SPI or I2C.

We have covered port expansion in the past, but that was with simpler circuits and logic gates. Port expander ICs are more intelligent, flexible devices and often easier to design with. Their cost is not significant, and it is always a good idea to be aware of different techniques available to solve your problem.

'Smarter' port expander ICs do not contain a microcontroller – just some carefully designed logic gates and interface circuits, and as we shall see shortly, a lot of functionality gets crammed into these chips.

Microchip's port expanders

It doesn't come as much of a surprise that Microchip manufacture port expanders, and we will be taking a look at one of their more interesting parts, the MCP23S17. This device provides 16 I/O pins, all with interrupt generation capability and a host of configuration options. The MCP range includes smaller devices with only 8 I/O pins, and either SPI or I2C communication interfaces. The communication interface is solely for controlling the I/O ports from a connected microcontroller and cannot be re-configured or put to another use.

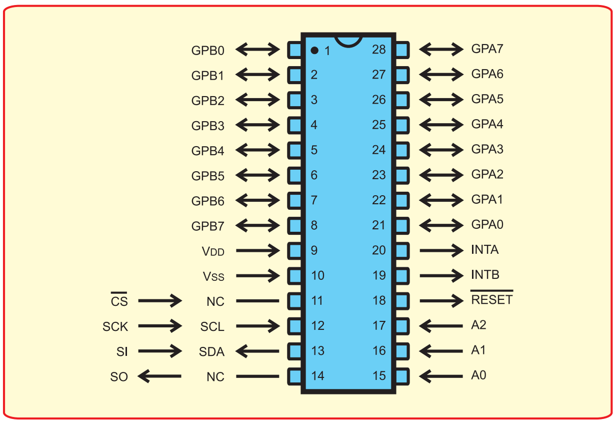

Fig.1. Pinouts for MCP23017 and MCP23S17

Using such an IC does require some special software to communicate over an SPI interface. We will present this software in next month's article, which means you can concentrate on using the device rather than worrying about the mechanics of connecting to it.

The software is quite straightforward and does not take up much space, which is important if you are thinking of using a small, code-space limited device. We will present designs based on bit-bashing (using ordinary processor I/O pins to transmit the SPI data) and on the standard SPI peripheral module (that will result in less code, but can only be used if your processor has such a peripheral.)

In Fig.1 is shown the pinout details for the MCP23017 and MCP23S17. The pinouts are so similar that only the interface pins differ. On the MCP23S17, the interface consists of the standard SCK, SI and SO communication pins (which are referred to as the SPI *bus*). The $\overline{CS}$ pin is the 'Chip select' signal, which must be driven low to place the device onto the SPI bus wires, and start a communication exchange.

The SPI bus is normally used with multiple devices connected to the SCK, SI and SO pins, each one having its own $\overline{CS}$ signal so that the devices can be placed onto the bus one at a time, and therefore not clash with each other. Microchip have added an extremely useful feature to the SPI interface, which reduces the number of processor pins required to address up to eight devices.

The IC has three address pins, A0, A1 and A2. You must connect these pins to either V_{DD} (to select a '1') or to V_{SS} (to select a '0'). These three inputs then define the 3-bit device address, which is specified in the initial SPI message sent to the device. If you have multiple devices connected in parallel on the SPI bus, each one with a different setting on the address pins, only the device that matches the address you specify in the SPI message will accept the message and respond. This way, with 16 I/O pins per device, you could conceivably have 128 additional I/O pins in your design and only require four I/O pins on your processor – more than enough for even the most demanding application!

MCP23S17 connections

The typical connections for an MCP23S17 are shown in Fig.2, with the address set to '000'. The four SPI bus signals can connect to any I/O pins on your processor, although if your processor does have an SPI peripheral it makes sense to connect the SCK, SI and SO signals to the appropriate peripheral pins. The $\overline{CS}$ signal is always driven from a standard I/O pin; the Microchip SPI module does not provide a special pin for this purpose.

In Fig.2, note the use of a simple resistor-capacitor circuit to provide a reset to the device. The MCP23S17 is quite a complicated device and does have some logic circuits that require a clear reset prior to use. A simple circuit, such as 100nF and 10kΩ should be sufficient.

Next month, we will show a circuit taking advantage of the multiple device addressing, showing how several MCP23S17s can be connected together.

There are several reasons for focusing on the SPI version of this device; The communication software is easier to understand and write; SPI is ten times faster than I2C, and there is little difference in the price between the parts. If you are more comfortable with I2C, and the reduction in speed is not an issue for you, then feel free to consider the MCP23017. The features the devices provide are identical.

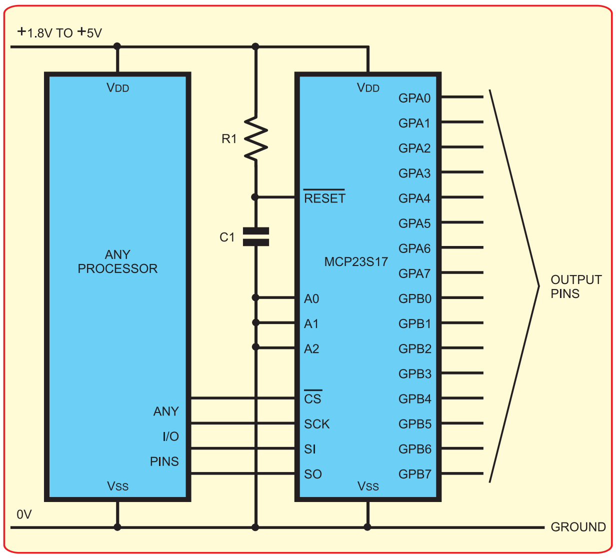

Fig.2. Typical connections for MCP23S17

Now to the crucial point – what features *do* we get in these chips?

There are 10 registers per port – eight more than most processors provide. The datasheet for the MCP23S17 is surprisingly complicated, running to 48 pages. This is simply because Microchip want to pack as many features into the device as possible for the price.

With such a simple chip, much of the cost is determined by the package. The silicon die also has to be a certain size to allow all the I/O pin wires to connect to it – so there is no point trying to save on device functionality when you have the silicon space anyway! Consequently, Microchip have thought of as many features and options as will physically fit on the silicon. Of course, you don't need to use all the features, and probably wont. It's nice to have the options, however.

Configuration options

The configuration registers break down into two groups of ten, duplicated between the two 8-bit ports, plus an overall control register. The common registers are suffixed with the letter A or B to indicate which port it is referring to. We will discuss the registers first, and then how to actually access them – which is more complicated than you might expect.

IODIR: This determines whether a pin is an input or an output, just as the TRIS register does on a PIC processor.

IPOL: Input polarity. An unusual register, this one; when a bit is set it causes the corresponding input port bit to be inverted in the input port register GPIO. It's difficult to think of a use for this, but the default setting of the register is all zeros, having no effect, so you can safely ignore this register.

GPINTEN: Interrupt-on-change enable. This register allows you to enable one or more pins to act as interrupt sources. When an interrupt occurs it simply causes one of the interrupt pins to change state. You can wire this pin to an interrupt pin on your microcontroller to receive immediate notification of a change of state on an input pin on the MCP23S17, useful for keyboard interfaces.

DEFVAL: This register works in conjunction with the GPINTEN register. When the interrupt-on-change feature is enabled, this specifies the 'default' expected value on the corresponding input pin. When the input pin takes on a value different to the value in DEFVAL, an interrupt is generated.

INTCON: This register also works in conjunction with the GPINTEN register. It specifies whether an interrupt is generated when an input pin changes state (toggles) or when it changes to a value that is different to the default value specified in DEFVAL.

GPPU: On a per pin basis, this allows an internal pull-up resistor to be enabled for the specified pins. This is a great feature for reducing external components, but bear in mind that the pull-up value is quite weak – 100kΩ – and is not accurately defined, so it could vary considerably between different ICs. By default, the pull-ups are disabled, so make sure you enable them for any unused I/O pin.

INTF: Interrupt status flag register; this register will indicate which bit, or bits, caused an interrupt. The bit will stay set in the register until the GPIO or INTCAP register has been read.

INTCAP: Interrupt capture register; this records the status on the input pins at the instant at which the interrupt occurred. This can be very useful for recording data at the precise instant that the interrupt occurred. After all, it could take several milliseconds from detecting an interrupt to actually reading the status of the input ports. Handy for interfacing to analogue-to-digital ICs perhaps.

GPIO: Port register; reading this register will return the status of the port pins. A write will cause any output pins to take on the value specified in the write.

OLAT: Output latch register; this register holds the value of data written to a port, either through this register or to the GPIO register. It's equivalent to the LAT register on the PIC18F devices.

Overall control register

Finally, there is an overall control register called **IOCON**. There are two copies of this register in the memory map of the device. The extra one is there for convenience. Seven bits within this register control overall operation of the chip. These are:

BANK: Selects whether the port A and port B registers are grouped separately, or accessed one after the other. This can help reduce the time it takes to read data from the two ports (if BANK = 0). There is little in the difference, so it is probably best leaving this at its default value of 0.

MIRROR: determines whether the chip provides a single interrupt output pin (MIRROR = 1) or one pin per 8-bit port.

SEQOP: Determines whether the internal address pointer of the device increments by one when an access is made to the device. Turning off sequential operation (SEQOP = 1) increases the speed at which a single port can be read (or polled) since it is not necessary to constantly resend the device address and command. For non-speed-critical applications it is probably better to turn off sequential addressing to help make your software more readable.

DISSLW: Slew rate control; this is the one and only configuration option for the SPI interface. Enabling this feature improves the reliability of SPI communication at high speeds or when there are many devices on the SPI bus.

HAEN: Hardware address pins enable; a strange option, this one. You can disable the use of the three address selection pins. If you disable the option you must still wire the pins to one of the supply rails, and you must still specify a value of 000 for the address bits in the SPI message. Best to leave this feature enabled.

ODR: Determines whether the interrupt output pins are push-pull or open drain. Open drain means that the pin can only drive the signal low, which means you can parallel up several open drain signals to the same pin. If you use open drain, you must provide a pull-up resistor, since the device can only pull a signal low.

INTPOL: When the ODR register is set to push-pull, this register determines whether the 'an interrupt has occurred' state is a high or low level.

Next month

In next month's article we are going to concentrate on using this chip as an output port expander, and so will ignore the interrupt facilities of the device. How you use the interrupt features is very specific to the particular application, but if there is interest in this subject then we will cover it in another article.

Each I/O pin can source up to 25mA, more than enough to drive an LED. Bear in mind, however, that the maximum current the device can manage overall is 150mA, so don't drive 16 LEDs at 25mA! The author finds that most LEDs work quite acceptably at 6mA to 8mA, so with care you could drive 16 LEDs without buffering.

Another great feature of the MCP23S17 is that it can operate down to 1.8V, which fits nicely with the operating voltage range of some of the small low-powered microcontrollers. You can easily drive a circuit from two AAA cell batteries, or a lithium 'coin' cell battery if the overall power consumption is low enough. When operating below 3V, however, note that the maximum SPI bus speed is reduced to 5MHz.

READOUT

Email: editorial@wimborne.co.uk

John Becker addresses some of the general points readers have raised. Have you anything interesting to say? Drop us a line!

All letters quoted here have previously been replied to directly.

★ LETTER OF THE MONTH ★

Sleep NOP

Dear EPE,

In Mike Hibbert's discussion of real time clocks he includes a section on the 'sleep' instruction. In his sample code the NOP instruction following sleep is extremely important, especially if you do as I do, put the processor to sleep once it has collected all its data. This is because when the processor is put to sleep it prefetches the next instruction; in this case the NOP, and in my experience if there is no instruction after sleep the processor resets.

Also, the Watch Dog Timer (WDT) should also be disabled in the configuration bits, as this will wake your processor in the absence of an interrupt. Microchip datasheets actually recommend to use the CLRWDT command before a sleep instruction, even if you have disabled the WDT in your configuration bits.

Peter Barrett MIEAust, via email

Thanks Peter, those are useful points you make.

ColdHeat soldering iron review

Dear EPE,

Alan's ColdHeat Soldering Iron article was a good review of this product – it's accurate and meets my experience with it.

In my use of the product, with alkaline batteries, it often refused to properly heat up (I was using it out in the yard to install PL-259 plugs) and the unit itself overheated. The batteries became too hot to touch, while the tip just shorted out, without getting hot enough to complete the solder joint. Also, I would not recommended it for use with NiMH batteries, which also became too hot to touch.

I returned it for a refund.

James Richards, Michigan, USA, via email

Thanks for the comments James.

Schematic software

Dear EPE,

I refer to Steve Liggett's letter, January 2008, about circuit diagram software. For several years, I have been using a freeware program called TinyCAD. Its schematics are not as nice as those in *EPE*, but are better than those from most schematic software. It can be downloaded from **tinycad.sourceforge.net** and was written by Matt Pyne of Milton Keynes. There is a good set of symbols included. Symbols may not always be consistent, as several were contributed by users, including myself, but you can usually find a useable one. It is also easy to draw new symbols and add them to the library.

Bill Stiles, Hillsboro, MO, USA, via email

That could be useful to readers Bill, thanks.

Mediation or median filtering

Dear EPE,

I would like you to cover in the *PIC n' Mix* column, the technique of mediation or median filtering, giving it your usual thorough explanation that helps less skilled people like me to understand how different programming techniques work and understand how to implement them with hardware in our own programming.

Until now, when I had to read some analogue values, and show them on a display without too much flickering of the numbers from reading to reading, I used to take a number of readings, and average them, before displaying, to reduce the flickering, but now I find this method is more useful.

It is basically a method that takes an uneven number of readings from the same A/D channel, puts them in an array, sorts them, and shows the value in the middle, thereby avoiding those noisy readings that could have pulled the average to one end or the other.

Since I have never heard or read anything about it in *EPE* I fear that it might be unknown to most readers. If you also think this is the case I hope that you will find the time and resources to introduce it to all of us in a future article in the magazine. This is the link to the **piclist** where I believe I found it first:

www.piclist.com/techref/microchip/math/medfilsort-mc.htm

For slow measurement (measuring with long intervals) I find it has an even smoother movement towards the correct result when I take only one new reading at a time, make it replace both the smallest and the biggest of the old readings, sorts them again and shows the middle, and then take one new reading, replacing top and bottom, and so on. The disadvantage of this last method is that you have to put aside a large number of memory bytes for each channel you want to measure and mediate on.

Niels-Ejner Carlsen, Denmark, via email

Thanks Neils, your letter has been passed on to Mike Hibbett.

SIP removal

Dear EPE,

I have read Alan's soldering tips page on your website. I am an experienced engineer, so I have much experience of working on these types of jobs.

I've often wondered if there are any 'cheap' tools available for reliably removing a 'SIP8' IC from a double-sided PCB? It's a normal (vertical dual op amp, NJM4580L) 8-pin in-line chip. On this occasion the components are very densely packed together, so it's impossible to see reliably on the component side of the board, or to cut the IC pins.

I've desoldered the pins as much as I can (the track print is very small so I'm fearful of the track lifting/breaking), but the IC is still not free, so there's still solder holding it, probably some inside the holes, and possible some on the component side.

Is there anyway to desolder (heat) all eight pins together, while gently levering the IC out. If so, what is it, and does it work well?

Anon, via email

Alan replies:

I understand the problem, and it will be very difficult without using professional reworking tools, especially in a densely populated board. In particular, multilayer boards are difficult, as it is almost impossible to desolder the plated-through holes. I have just repaired a laptop motherboard which needed a new DC power jack. It only had five terminals, which were large and easily accessible, but getting the very last dregs of solder out of the wells was impossible (and you risk wrecking the board). In the end, I followed some advice from Magenta Electronics and used a Dremel cutting disc to slice off the socket, leaving the pins in place, which were then desoldered as normal – nerve-wracking stuff.

I feel there is little hope of getting the SIP out using traditional methods, because of course all eight joints need to be cleared before the part can be removed, and there will be tiny whiskers of solder still within. I find desoldering braid remarkably successful at times – maybe try adding fresh solder, then try to desolder with braid?

Perhaps you could try to fabricate something based on an existing tip from a manufacturer like Antex (**www.antex.co.uk/prodtype**), or make something up out of a small block of copper or aluminium? A model engineer may be able to fabricate something for you for a small cost.

Alan Winstanley, via email

Web browser security again

Dear EPE,

Reading Alan's response to my previous letter, I fear I must not have explained myself very well.

I was not proposing Linux as an alternative to Windows, but as a security solution *for* Windows, in a similar way that using third-party anti-virus software, firewalls, spy-ware, etc is a security solution for Windows. If you use a system that is immune from viruses to access the domain from which most viruses are caught, and

keep the vulnerable system isolated from this environment you have a 'foolproof' solution.

I am saddened by Alan's preconceptions that Linux is for the 'computer enthusiast', and that software and hardware support is limited. My household has been happily using Ubuntu for 18 months, including my son (now 7) and wife, neither of whom could be considered 'computer enthusiasts'. I have not had a single piece of mainstream (printers, graphics cards, DVD writers, USB memory sticks) hardware that has not worked 'plug and play', which is somewhat contrary to the experience a work colleague has had with Vista. He has come to the conclusion that to use Vista successfully he will have to buy new 'Vista' hardware.

The Windows security solution I have described is no more difficult for a mainstream user to implement than installing (and using and updating) anti-virus software, firewalls, spy-ware programs (various), and then implementing the constant stream of Windows security updates that slow the machine down for ages while they install and demand to reboot the computer at what is normally a most inconvenient time.

Alan described in his response to Doug's email how it was not feasible to run Spy-ware Doctor in the background, as it is too resource intensive. Move Windows to an environment where it does not need extras to keep you safe, and Windows suddenly becomes much nicer to use, and more responsive.

I accept Alan has to allow for the mainstream, but if you do not venture outside of the mainstream box you would never get to FireFox, and all anti-virus software and firewalls would be Norton and McFee only, nothing else. A sad fact is the true mainstream user (which I do not think *EPE* readers on the whole are), that surfs the Internet, sends emails and photos, and types and prints the occasional letter, needs nothing more that Ubuntu provides.

On the question of mainstream, it may interest you to know that both Dell and Tesco are selling PCs pre-installed with Ubuntu (fairly mainstream companies I would say!)

The Windows security solution I have described is free, and probably as secure as you can get.

Graham Harby, via email

Alan replies again:

Graham makes some valid points that I don't disagree with. Many web servers run Linux and never miss a beat, including the *EPE Chat Zone* server at **www.chatzones.co.uk**. Our problem is that rightly or wrongly Linux is not the operating system used in the mass market. My *Net Work* column is written for the mainstream Internet user, where Windows is ubiquitous (XP preferably), so in our context, a feature on Linux is more appropriate for computer hobbyists and enthusiasts. I hope to install Linux on a spare PC when I get the time, once I've become familiar with Vista.

While it is hard to cover Linux, or Apple MAC OS in our electronics magazine, I don't dispute the cost benefits and superiority in some respects that Linux has, and the sheer elegance and usability that the MAC OS offers as well. In my view this is offset somewhat by the challenge Linux poses for software and hardware/driver choice, the need to be more of a 'computer enthusiast' and the reduced choice of peripherals and software available to Linux and MAC users (I sympathise).

It is indeed not healthy that most computer users have been conditioned by market forces into using Windows, and you are right to wave the flag for alternative operating systems. The trend now is towards virtualisation, with a powerful computer system running in the background that renders a variety of operating systems up front to the user, as you rightly say.

Alan Winstanley, via email

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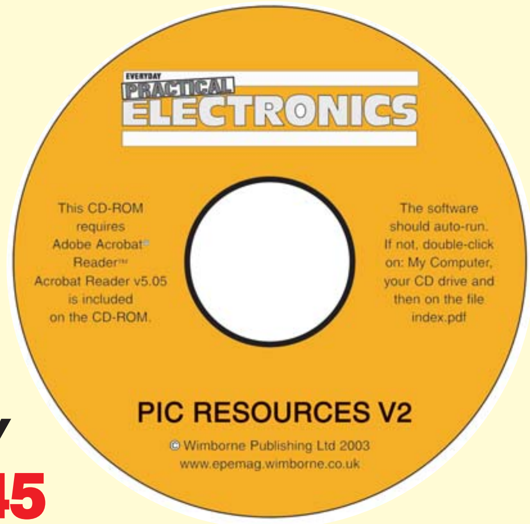

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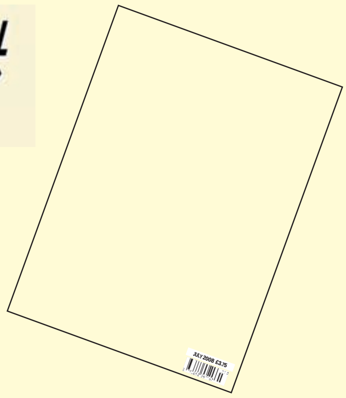

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Net Work

Alan Winstanley

A fishy experience

Many years ago, I found myself enjoying a working breakfast in a fishing town, sharing a table with no one less than the mayor of Grimsby. (I have had a penchant for peppered mackerel ever since.) Over a plateful of delicious seafood we were regaled with a breathless marketing presentation from British Telecom, intended to celebrate the imminent arrival of broadband services in the locality, and to generally stoke up the excitement.

This was at a time when the country was engaged in a technological type of national lottery – BT had previously throttled the roll-out of broadband across the country and each local telephone exchange was assigned a cruel 'trigger level' that indicated the level of local interest in broadband. This scheme was also driven by the practical fact that BT had to prioritise the phased expansion of broadband and could never be expected to roll out ADSL overnight across the whole country.

Furthermore, BT was emphatic that, for reasons involving geography and numbers, customers in some regions would never experience the twinkling LEDs and bounteous bandwidth of their own ADSL router. It took political intervention to force BT to address problems of availability. Perversely, those in Britain's isolated rural areas whose lives would have benefitted proportionately more from broadband than their urban cousins were, of course, left until last.

Back to the seafood breakfast. At a time (around 2001) when most users relied on V.90 dial-up Internet or even early satellite trials, apart from email and web surfing, the 'killer application' for many was maybe eBay or Amazon. The sales presentation from BT focussed on the many benefits that broadband would bring, including faster access from an always-on service, savings in time and improved productivity, and utilising greater bandwidth to stream video or audio services. Generally, we would be able to do so much more at the dizzying rate of 512kbps without having those modem dial-up tones interrupting our pleasure.

The entire thrust and conclusion of the BT presentation at the time, though, was that there were no online 'killer' services available that made broadband the 'must-have' service for subscribers. The delegates, who included local business owners, web designers and developers were all urged to get to grips with the potential of delivering video or higher-bandwidth applications to consumers. It was as though bucket loads of bandwidth were about to arrive in town and no-one really knew what to do, because of our pre-conditioning to dial-up access.

Fast forward seven years to today, and we can now view entire television programs on demand via a web browser. *BBC Television's* iPlayer (**www.bbc.co.uk/iplayer**) and its commercial rivals such as *ITV* (**www.itv.com/CatchUp/**) and *Channel 4* (**www.channel4.com/4od**) are vying to broadcast their output to UK consumers via the Internet, digital rights management (DRM) permitting. Even satellite operator *Sky TV* (**www.sky.com**) is reportedly moving towards video on demand delivered via the ethernet port installed on Sky+ hard drive recorders. Connecting it to your broadband router yields the prospect of downloading Hollywood movies onto the hard drive via the Internet instead of a satellite dish.

In the home

Local area network technologies such as wi-fi or the devolo Home Plug (see **www.devolo.co.uk**) can deliver network access around the home. Interesting PC peripherals that have been available for several years include the Slingbox (see **www.slingmedia.com/**), a TV adaptor that streams home TV programs through the internet onto a PC or laptop, mobile phone or Blackberry, whether in the next room or halfway around the world – reliant of course on having a half-decent internet connection. Online gaming using the Xbox or Nintendo Wii shows another direction in which more demand for bandwidth lies.

By building IP structures into the electronics, webcams, security devices and even humble domestic appliances can be managed in a community network using, for example, LG's HomNet. Korea's LG offers a 'tomorrow's world' view of the future using HomNet at **http://tinyurl.com/6x8mnd**. LG envisages a Star Trek-like society in which its HomNet networks could report on your health and well-being; monitor for intruders while you are away; report the arrival of vehicles; detect gas leaks; provide local news and weather and monitor the welfare of elderly residents.

In fact, the electronics technology to do much of this is already established. Capturing data via interface systems and processing it is not the problem. Today, the crunch is in servicing our spiralling broadband consumption of data on creaking phone lines that were only intended for voice calls. Not for us, it seems, a high speed fibre optic network or the cable access that the Japanese enjoy. BT continues to trial its advanced IP-based network called 21CN (**www.btplc.com/21CN/**), which will ultimately form the core of our voice and data networks delivered to the home.

ITV.com is the latest TV station to provide programmes downloadable over the internet

Such has been the spike in consumption due to TV streaming that an argument now rages as to whether the BBC iPlayer and others are morally justified in unleashing their 'killer' applications onto the web, without so much as a thought for the ISPs that carry the traffic. Presumably, the success of the iPlayer site is reflected in the BBC's own hosting costs, and while the iPlayer has clearly wrong-footed the sector, the BBC can hardly be penalised for providing engaging content that the broadband providers were desperate for at the start of the millennium.

Readers can email Alan at: **alan@epemag.demon.co.uk.**

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I. D. Poole

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This book has been written with the average electronic hobbyist in mind. Technical language and mathematics have been kept to a minimum in order to present a broad, yet clear, picture of the subject. The radio amateur, as well as the short-wave listener, will find explanations of the propagation phenomena which both experience in their pursuit of communications enjoyment.

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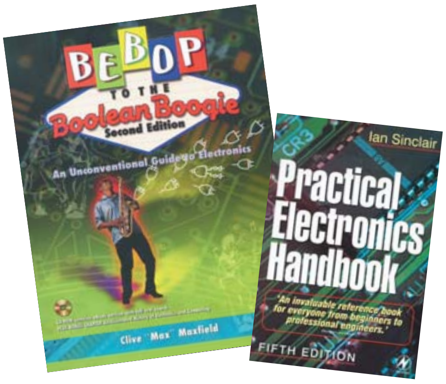

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R. A. Penfold

This book provides a number of practical designs for video accessories that will help you get the best results from your camcorder and VCR. All the projects use inexpensive components that are readily available, and they are easy to construct. Full construction details are provided, including stripboard layouts and wiring diagrams. Where appropriate, simple setting up procedures are described in detail; no test equipment is needed.

The projects covered in this book include: Four channel audio mixer, Four channel stereo mixer, Dynamic noise limiter (DNL), Automatic audio fader, Video faders, Video wipers, Video crispener, Mains power supply unit.

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VIDEO PROJECTS FOR THE ELECTRONICS CONSTRUCTOR
R. A. Penfold

Written by highly respected author R. A. Penfold, this book contains a collection of electronic projects specially designed for video enthusiasts. All the projects can be simply constructed, and most are suitable for the newcomer to project construction, as they are assembled on stripboard.

There are faders, wipers and effects units which will add sparkle and originality to your video recordings, an audio mixer and noise reducer to enhance your soundtracks and a basic computer control interface. Also, there's a useful selection on basic video production techniques to get you started.

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Circuits include: video enhancer, video fader, horizontal wiper, improved video wiper, negative video unit, fade to grey unit, black and white keyer, vertical wiper, audio mixer, stereo headphone amplifier, dynamic noise reducer, automatic fader, pushbutton fader, computer control interface, 12 volt mains power supply.

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FAULT FINDING, CIRCUITS AND DESIGN

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The associated CDROM contains the book in PDF format, MPLAB (plus instruction manuals in PDF format) and all the programs covered in the book as assembler (ASM) files. Those that wish to programme their own PICs will require a PIC programmer.

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